PHD

Genotype independent aspects of seed ecology in Taraxacum

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GENOTYPE INDEPENDENT ASPECTS OF SEED ECOLOGY

IN *TARAXACUM*

submitted by June Tweney

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Abstract

Five capitula of *Taraxacum* species from each of five sites were collected in and around the University of Bath. The achenes from each capitulum were weighed individually and the number and weight range recorded. These achenes provided the material for the experiments reported in this thesis. Achenes were germinated and grown in a variety of situations. Achenes were also dissected to establish the relationship between fresh achene weight and embryo weight and length. This work indicates that all plants studied produce capitula with a unique weight range and number of achenes. Achene weight, and in consequence embryo weight, is the critical factor in determining germination success. Heavier achenes have a better germination rate than lighter achenes. Any advantage in having germinated from a heavier achene persists during early seedling establishment, but diminishes with plant age. Achene weight affects flowering in field conditions, but has no influence on greenhouse grown plants. In the natural environment, there is a consistent pattern to reproduction, with most plants producing more capitula in the first year than in the second. This pattern is independent of clone identity, although flowering behaviour within a clone remained constant for both years of the experiment. This research ends with environmental sensitivity experiments that indicate that four of the five clones used in this research are able to tolerate a wide range of environments.

Acknowledgements

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Chapter 1

1.1 Introduction

The aim of the research reported in this thesis is twofold. First, it is to investigate the effects of achene size on seedling and post-seedling performance in *Taraxacum* apomicts (including the reproductive output of individuals over two seasons). Second, it is to provide broad insights (by using *Taraxacum* apomicts as biological controls) into the relative importance of seed size and seed genotypes in seedling performance in flowering plants.

The thesis is structured in the following way:-

Chapter 1 provides an introduction to the relevant literature on seed/seedling ecology, on *Taraxacum* and on apomixis. Its aim is to describe the context within which the research reported in the remainder of the thesis has been undertaken.

Chapter 2 begins with a description of the experimental material used and then describes an investigation into the relationship between achene weight, embryo weight and achene coat weight. Its aim is to look closely at the pre-germination stage and the relationships between these variables.

Chapter 3 describes an investigation into the relationship between both the weight and age of achenes and viability and time to germination. It also reports on germination and seedling establishment in the field and ends with a brief look at germination of excised embryos *in vitro.*

Chapter 4 describes greenhouse-based investigations into the pattern of growth during the post-germination stage and the extent to which variation in this pattern is associated with variation in achene weight. Its aim is to provide a broad overview of growth by way of a leaf turnover experiment and other experiments using destructive and non-destructive methods of assessing growth.

Chapter 5 describes an investigation into achene production. Its aim is to establish whether there is a relationship between flower number (i.e. position of a capitulum in the flowering sequence) and total achene number, total achene weight and mean achene weight.

Chapter 6 describes an investigation into growth under natural (i.e. field) conditions. It includes an analysis of environmental sensitivity.

Chapter 7 comprises a concluding discussion.

1.2 Seed size and seedling performance.

It has been observed for some time that many species of flowering plants produce seeds that show differences in both morphology and weight. Seed size has been positively associated with germination requirements (Cavers and Harper 1966; Williams 1971; Leishman and Westoby 1994), percentage germination (Schaal 1980; Weis 1980; Zimmerman and Weis 1982; Stanton 1984; Dolan 1984; Kane and Cavers 1991; Prinzie and Chmielewski 1994), competitive ability (Black 1957; Twamley 1967; Harper and Obeid 1967; Stanton 1984), growth rate (Gross and Soule 1981; Choe et al. 1988; Maiti et al. 1990; Shipley and Peters 1990; Zhang 1994) and seedling survival (Schaal 1980; Morse and Schmitt 1985). In reviewing previous work on patterns of seed weight, Cavers and Steel (1984) noted that within a species, seed weight differences occur for plant populations separated by great distances and between habitats which exhibited differences in moisture, temperature and photoperiod. Moreover, studies with several species have shown that seed weight within a population tends to decline from earlier to later seeds produced in a season (Rorison 1973; Turner *et al.* 1979; O'Toole 1982); for example, work with *Amaranthus retroflexus* L. and *A. powelli* Wats. has demonstrated a marked decline in seed weight from early to late-maturing seeds (McWilliams et al. 1968; Schrimpf 1977).

Previous to the work of Cavers and Steel (1984), very little was known about changes in seed size with time within individual plants in a single population, although Frost (1971) had recorded that the mean weight of seeds of *A. powelli* decreased as the season progressed .

Cavers and Harper (1966) noted different responses in their work on the germination of *Rumex* spp.. Individuals of *R. crispus* and *R. obtusifolius* often produce several inflorescences in a single year. The inflorescences produced by an individual do not arise at the same time, but dates of flowering on any two panicles may be very close to one other. Cavers and Harper (1966) showed that there could be differences in germination requirements between seeds from different panicles on the same plant, but these differences were, in general, smaller than those between seeds of different plants. They also compared germination of seeds borne at the proximal and distal positions on the panicle branches. Seeds from the proximal ends of the branches were found to be heavier than those from the distal ends. The morphology of the seeds was found to be variable, with seeds from the proximal ends having more appendages on the pericarp. Proximal seeds were more specialised in germination requirements and germinated more slowly. However, once germinated, these heavier seeds produced larger, faster growing seedlings, with a larger cotyledon area. Larger cotyledons have been shown by Black (1957) to be of great selective value in a highly competitive environment. With *Rumex* species and weed species in particular, polymorphism would be immensely important in allowing a species to exploit a range of germination microsites. It would enable the seeds from a population (or, in some cases, from an individual) to germinate over a period of many years, with each seed germinating only when its closely circumscribed requirements for moisture, light and/or temperature were met. Intermittent germination is a well known characteristic of both *R. crispus* and *R. obtusifolius* and is undoubtedly a crucial factor in their successful role as weeds. Cavers and Harper (1966) consider that polymorphic form is most probably genetic in nature. They argue that the great differences observed in germination behaviour (closely linked to seed size and weight) between seeds from different plants growing in the same habitat, indicates that seed polymorphism has survival value. Williams (1971) has argued that hybridisation has played an important role in the origin of polymorphic germination in *Rumex*.

Cidiciyan and Malloch (1982) have studied the effects of seed size on the germination, growth and competitive ability of *Rumex* species. The main conclusions arising from their study are: a) percentage germination is not affected by seed size, but germination rate increases as seed size decreases in *R. obtusifolius*; b) in *R. obtusifolius*, initial growth is slower in plants germinating from smaller than from larger seeds, but by the end of the first growing season of 133 days, the growth of plants from smaller and larger seeds is the same; c) under intraspecific competition, plants grown from small seeds of *R. obtusifolius* and *R. crispus* are smaller at maturity than plants grown from large seeds. The results of this investigation and that on the effects of grazing of *R. crispus* and *R. obtusifolius* by the dock beetle, *Gastrophysa viridula* (Bentley and Whittaker 1979; Bentley, Whittaker and Malloch 1980) show that plants from lighter seeds grow and compete less successfully than those from heavier seeds. Insect grazing has both a direct effect on the plant grazed and an indirect effect on the success of the next generation of plants, as grazing reduces leaf area. This defoliation causes a reduction in seed weight per panicle and in the weights of individual seeds (Maun and Cavers 1971; Bentley and Whittaker 1979; Bentley, Whittaker and Malloch 1980).

More recent research linking the role of seed size with insect damage has been conducted by Bodnaryk and Lamb (1991) who worked with *Brassica napus* L. and *Sinapis alba* L., (oil seed rape and mustard, respectively). In both choice and non-choice feeding tests with the flea beetle *Phyllotreta cruciferae* (Goeze) they found that the proportion of damage to cotyledons in both species was highest for seedlings grown from small seeds.

The proportion of seedlings killed by the flea beetle was also highest among seedlings from small seeds. They conclude that 'big seeds' appears to be a desirable trait that enhances crucifer seedling resistance to flea beetle attack and results in increased seedling survival.

Shipley and Parent (1991) studied seed size in relation to germination, minimum time to reproduction and seedling relative growth for 64 wetland species. They report that seed size is not associated with any of the germination attributes. However, the experimental approach adopted can be criticised. The authors comment that seeds for the experiment were removed from cold storage and that this caused problems for some of the species studied; the authors do not specify the problems. Twelve out of the original 64 species had less than 10% germination during the experiment, seven had known very low germination rates and one germinated during the storage period. Mean seed weight was calculated from a sample of 25 seeds, although 100 seeds per species were used in the experimental work. The authors undertook a literature survey of the relationship between seed size and seedling relative growth rate involving seven studies and 204 species. They found that 'the relationship was weak and variable'.

Quite the opposite conclusion emerged from a study of the role of seed size and seedling vigour in pearl millet, *Pennisetum typhoides*, (Maiti, Raju and Bidinger 1990). Several different genotypes were studied. Highly significant positive correlations between seed size and both seedling weight at emergence and at 7 and 15 days, and efficiency of mobilisation of seed reserves were found. They conclude that these attributes account for a proportion of the variation in seedling size material which supports growth during heterotrophic and transitional (to autotrophic) growth periods.

Haig and Westoby (1991) examined seed size in angiosperms represented in the fossil record and among extant species. They were looking for a relationship between costs of seed production and the lower limit to seed size. They conclude that 'species with smaller seeds will not gain as great a benefit from decreasing seed size (in order to produce more seeds) as will species with larger seeds. Species with smaller seeds will require a greater proportional decrease in food reserves per seed (and probability of seedling survival) to achieve the same relative increase in seed number. However, the exception to this is the *Orchidaceae*. This group produces minute seeds that are much smaller than the lower limit to seed size suggested by Haig and Westoby. Orchid seeds require the presence of a symbiotic fungus to germinate.

In experiments with *Lychnis flos-cuculi*, Biere (1991) attempted to distinguish between the factors contributing to seed size, germination and seedling size. Nuclear genetic, maternal, paternal, environmental and inbreeding effects were studied. Maternal effects predominated in the determination of seed size and germination characteristics but the maternal environment during seed development was less important than the maternal genotype. Maternal effects on seedling size decreased with time. The author commented that this 'was regarded as a common phenomenon'. Biere's (1991) paper is the only one reviewed that attempts to classify the various components in the cycle, seed---plant growth---maturity---seed.

1.3 Seed size, experimental controls and apomixis.

All species discussed in the previous section reproduce sexually. Consequently, different seeds produced by the same plant will differ genetically with respect to embryo and endosperm genotypes, but not with respect to maternal tissue. This complicates the study of the relationship between seed size and seedling/post-seedling performance as a detailed understanding of this relationship will require an understanding of how both genotypic differences between seeds, and genotype x environment interactions, influence seed size and seedling/post-seedling performance. That is, any variation in seedling/post-seedling performance may be due in part to variation in seed size, but also to variation in seedling genotypes and to interaction effects. To my knowledge, there has been no successful attempt to partition the variance in this way. Because of this, the relative importance of environmental and genetic factors, and of the maternal genotype compared with those of the embryo and endosperm, are poorly understood. Positional effects (Cavers and Harper 1966) provide strong circumstantial evidence that maternal environment can have an important effect on seed size (Biere 1991). However, it is clear that if there is a selection pressure for ovules to select pollen, and for pollen to select ovules that are in favourable positions (Mulcahy 1979; Marshall 1988), then the genotype of an embryo or endosperm is not necessarily independent of its position within an ovary. As a result, the 'best' (e.g. most competitive) embryo/endosperm genotypes may be in the best positions on the plant. Consequently, a seed may be large not only because of its position, but also because it encloses an embryo and endosperm which have genotypes which are able to attract a greater than average supply of resources. There is very little evidence for or against the hypothesis that the genotype of the embryo or endosperm affects the size of the seed. However, it is important to acknowledge that seedlings germinating from large seeds might survive better and be more vigorous and competitive than those produced by small seeds partly because they have well adapted genotypes and not simply because they have developed within larger seeds (Queller 1983; Mogie, Latham and Warman 1990).

One way of separating the relative contributions of environmental and genetic factors to seed size and seedling performance is to hold the genotypes of the seeds constant. One form of reproduction that achieves this naturally is autonomous (non-pseudogamous) apomixis. The combination of meiotic restitution, parthenogenesis and autonomous endosperm development provides genetic uniformity among the three components of the maturing seed (i.e. the embryo, the endosperm and the maternal tissue, although the endosperm will be at a higher ploidy level than the embryo or maternal tissue if it is initiated by the fusion of polar nuclei) and among seeds produced by an individual or lineage. Of course, even this pattern of reproduction does not guarantee complete genetic uniformity as genes may be altered by mutation or their position in the genome may be changed by recombination or chromosome rearrangements (e.g. translocations and inversions). But there is no reason to suspect that this level of genetic change will usually have a significant effect on seed/seedling performance.

One group of autonomous apomicts that is eminently suitable for an investigation of genotype independent aspects of seed ecology is *Taraxacum*. Seeds of *Taraxacum* are individually enclosed within single seeded fruits known as achenes. Achenes are grouped together in capitula, with each capitulum often bearing between 200-400 achenes. An individual plant will produce many capitula during a single flowering period (over 20 is not uncommon). In common with other Asteraceae, the seed coat is fused with the achene wall. Morphologically the achene is a fruit, but it functions ecologically as a seed. The seed is never released from the achene during dispersal or at any other time. One further advantage of using this genus to investigate the relationship between achene size and seedling/post-seedling performance is that, in the mature achene, the endosperm is reduced to a few crushed cells and its contribution to mature achene weight can therefore be ignored. (The reserves of the endosperm are absorbed by the maturing embryo.) The weight of a mature achene therefore consists of two parts:- the embryo and the merged achene wall and seed coat. Whenever achene weights of *Taraxacum* are mentioned in this thesis, the weight refers to the weight after the pappus has been removed.

1.4 The genus

Individuals of *Taraxacum* aggregate are rosette forming polycarpic perennials with long, stout tap roots. Over 230 microspecies (agamospecies) have been recognised in Britain and there are possibly over 1500 worldwide. The genus is found in a wide range of habitats, including gardens, waysides and pasture, and is a component of sand dune, mountain and wetland communities. This ecological diversity is related to the existence of many ecotypes. Some generalisations about the ecology of this group may be made from limited field observations and from the work of Richards (1972) and Sterk *et al.* (1983). Plants from the Section *Taraxacum* (reclassified as *Ruderalia*, 1997) are robust and are mainly found in fertile, disturbed, artificial habitats and include the taxa which are familiar garden and pasture weeds. Those from the Section *Erythrosperma* Dahlst. are associated with dry sandy or calcareous soils. They are generally much smaller in all their parts than taxa from Section *Ruderalia*. Taxa from Section *Spectabilia sensu lato* (Richards and Hawarth 1984) occur in moist, often less fertile soils and less trampled or grazed sites than those in which Section *Ruderalia* is abundant. Other Sections are associated with montaine habits or with sand dunes or mire. In the Netherlands, a reduction in the intensity of land management has resulted in Section *Taraxacum* being replaced by Sections *Spectabilia* and *Palustria* Dahlst. In drier habitats Section *Erythrosperma* becomes more prominent (Grime *et al.* 1988).

The tap root often penetrates deeply into the soil and allows the exploitation of sites where the mineral subsoil is covered with debris, such as paving stones and building rubble. In sandy habitats, the tap root appears to be of critical importance in providing the plant with access to subsoil moisture. In pastures, *Taraxacum* often includes the species preferred by stock. They are capable of rapid recovery after defoliation and are resilient under trampling damage. In part this resilience is due to the presence of contractile roots which pull the apical meristem 10-20mm below the soil surface (Sterk *et al.* 1983). Early growth of foliage and early flowering, both of which occur before appreciable growth of many grasses has occurred, may also be a key feature in the success of this species in pasture (Sterk *et al.* 1983).

Fruits (achenes) of *Taraxacum* are buoyant in air and are released in large numbers during early summer. It is thought that upwards of 2000 or more achenes are released per plant per season (Salisbury 1942), or about 5000m^{-2} in pastures (Sterk *et al.* 1983); these are capable of germinating over a wide range of temperatures. This combination enables *Taraxacum* to be a highly effective coloniser of sites with exposed soil. No persistent seed bank is formed, but in the event of disturbance individuals may regenerate by means of fragments of tap-root. Larger plants often form multiple rosettes. Species differ genotypically in the extent of their allocation of resources to vegetative growth and to achene production (Solbrig and Simpson 1974, 1977) and in a variety of characters related to growth and morphology, including relative growth rate (Roetman and Sterk 1986). Micro-species from less-strongly fertilised and less-heavily grazed pastures tend to have a broad ecological range; those of fertile, intensively grazed habitats are more specialised and are probably among the most recently evolved taxa (Sterk *et al.* 1983).

Overall the number of species within the aggregate is probably still increasing, particularly in Section *Ruderalia*, (Grime, Hodgson and Hunt 1988) which includes the majority of populations exploiting fertile and disturbed lowland habitats. The status of other Sections is less clear but some which exploit fens and water meadows, particularly Section *Palustria* Dahlst., are clearly declining (Richards 1972). Sexuality is not uncommon in Section *Ruderalia* (Sterk *et al.* 1983). Since the discovery of a high incidence of sexuality in Central Europe and the recording of diploids in The Netherlands (Sterk *et al.* 1982), the possibility of hybridisation and the advent of new variants or even new microspecies, and hence the evolution of new taxa capable of exploiting disturbed fertile habitats is probably proceeding.

The genus comprises some 2000 extant species grouped into over 30 sections. Of these species it has been estimated that 90% are obligately apomictic, the remainder being divided into facultative apomicts and obligate sexuals (Richards 1973). The facultative and obligate apomicts are invariably polyploid, and are typically eutriploid or eutetraploid; obligate sexuals are invariably diploid. The apomicts reproduce by non-pseudogamous diplospory with parthenogenesis (generative apomixis -Mogie 1988, 1992). The sexual species are mainly self-incompatible outbreeders. Pollination is insect mediated. All sexual taxa, and the majority of apomictic taxa, are hermaphroditic, although some 250 apomictic forms are male-sterile (personal communication from Richards, in Mogie and Ford 1988). Facultative apomicts can reproduce both sexually and apomictically. It is not known whether the incidence of of apomixis can be affected by environmental factors, such as photoperiod, although this has been observed in other apomictic groups, for example, in *Eragrostis curvula* (reported in Mogie 1992). Hybridisation occurs between diploid sexual taxa and pollen-bearing apomictic species (Richards 1970 a,b; Stace 1975; Mogie and Ford 1988) and this may have been important during episodes of speciation (Richards 1972). In Europe, an estimated 10% of taxa are diploid, 45% triploid, 28% tetraploid, 5% pentaploid and around 10% aneuploid (Grime, Hodgson and Hunt 1988). According to Richards (1972) only two native taxa were thought to be diploid and sexual.

I know from investigations in the greenhouse prior to the experimental investigations reported in this thesis that the material used are obligate apomicts.

Chapter 2

2.1 Experimental Material

2.1.1(a) Collection of Initial Material

The initial experimental material consisted of *Taraxacum* capitula collected from 3 locations in and around the campus of the University of Bath. The 3 locations were: meadow, an area of open managed meadowland with the grass mown after seed setting; wall, a shady area of little disturbance; and "ski-slope", an area of open habitat, mown at irregular intervals. Capitula were given code letters relating to their location: M, W, and S respectively. From each location one capitulum per plant was collected from 5 plants growing between 10 and 20 metres apart. It was hoped that this sampling regime would result in the capitula being produced by different clones, as it is known that there is usually considerable genetic variation (both inter- and intra-specific) within a population of *Taraxacum* (von Hofsten 1954; Sterk, Groenhart and Mooren 1983; Ford and Richards 1985). Each capitulum was labelled and stored in a paper packet.

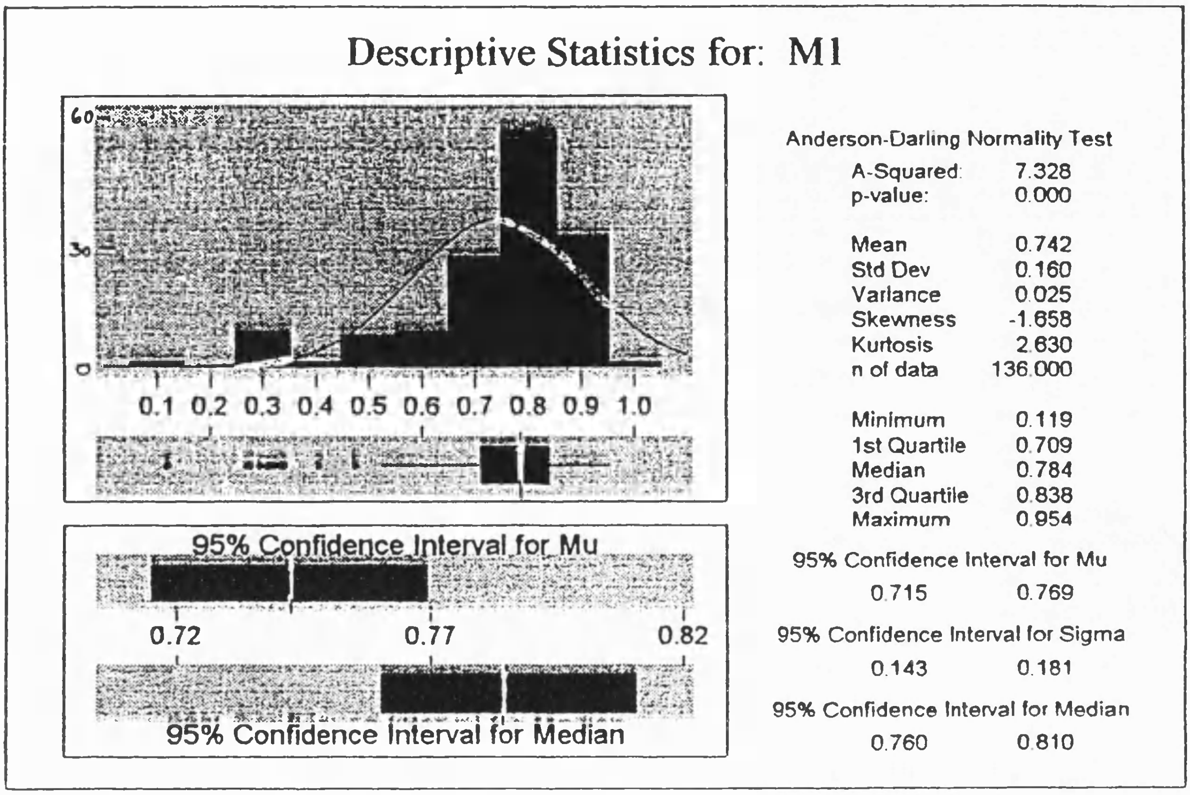
2.1.1(b) Description of Initial Material

The achenes were cleaned and the pappus was removed prior to the achenes being weighed individually (to 0.0001mg) on a Mettler UMT2 microbalance. The distribution of achene weights for each capitulum is represented graphically in Figure 1, using the Minitab statistics package. Box plots have been included in the exploratory data analysis as they provide a summary of statistical information and can be more informative than histograms alone (Ellison 1993).

Figure 1

The distribution and weight ranges of achenes from initial individual capitula.

(a)



Note:

The Anderson-Darling Normality test :

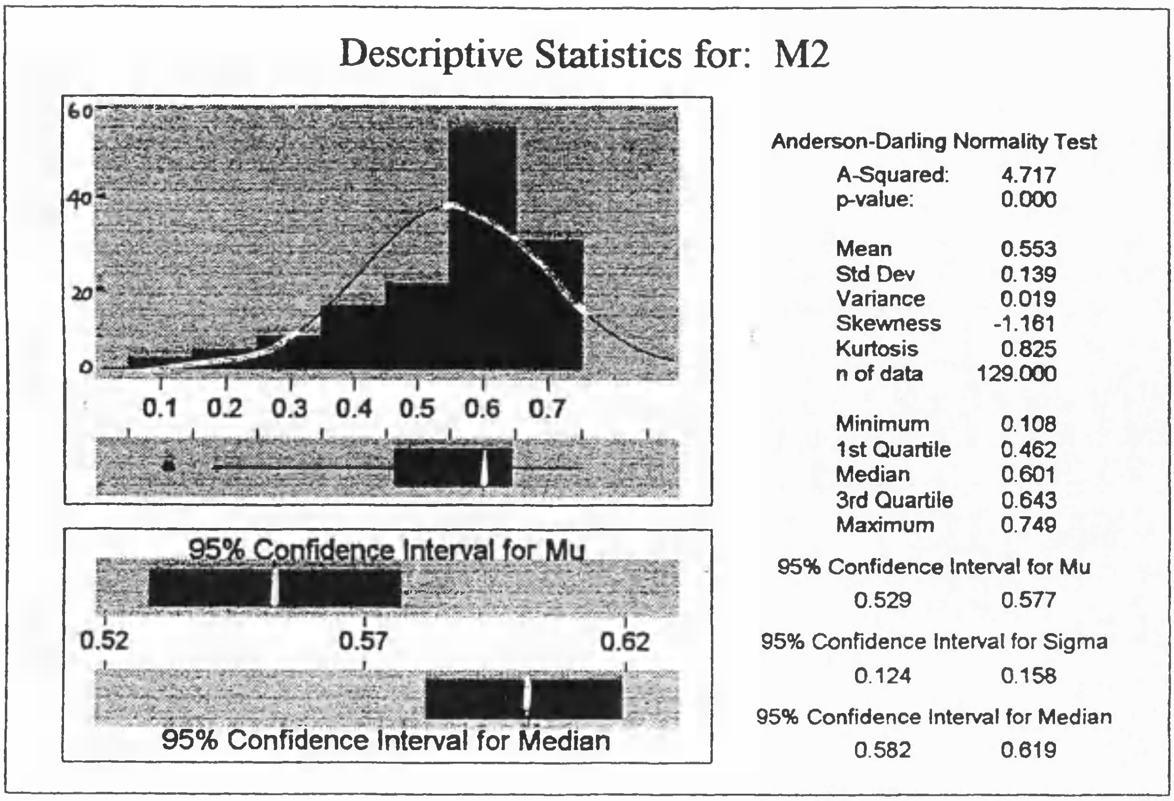
This tests the given distribution against a normal distribution with the same mean and variance. The A^2 value gives an indication of evidence for a non-normal distribution at a probability level p=0.000.

n of data number of achenes on capitulum

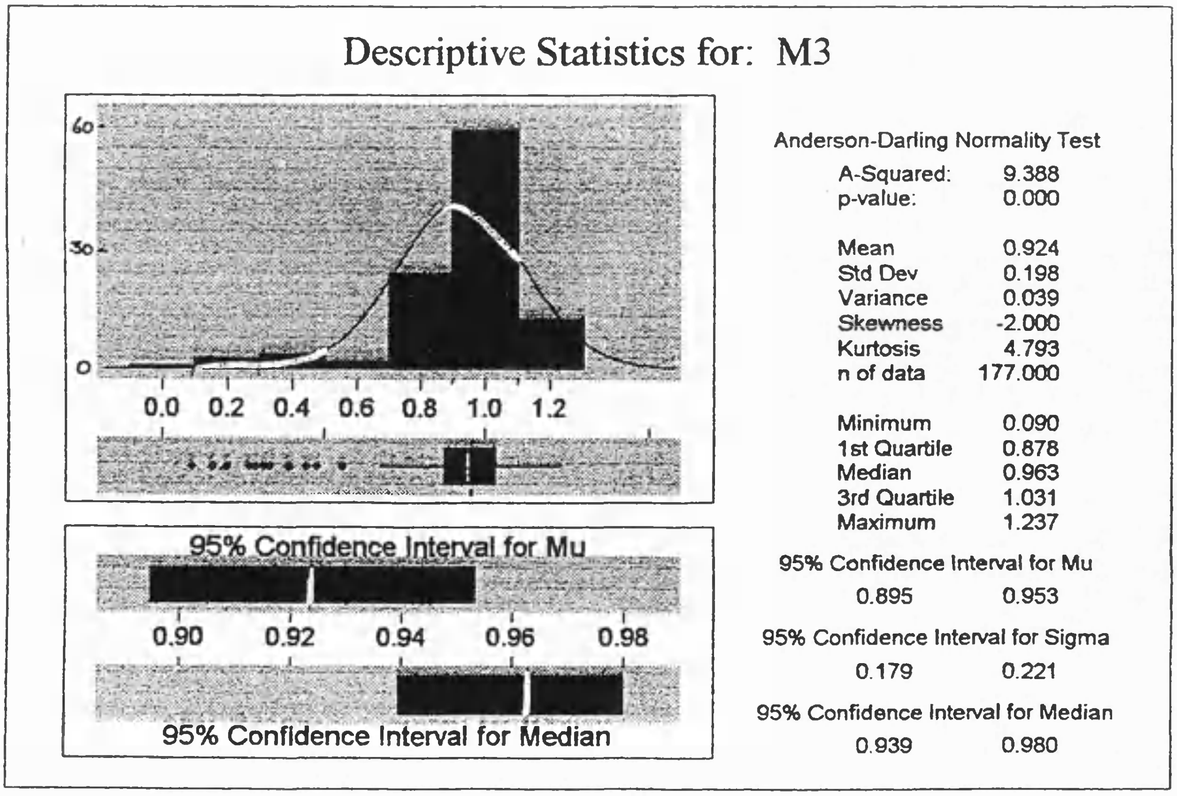
Mu mean value of fresh achene weight
Sigma standard deviation

The graphs of distribution of achene weight (mg) per capitulum have the following labels:
x-axis: 'fresh achene weight in mg.'
y-axis: 'number of achenes'

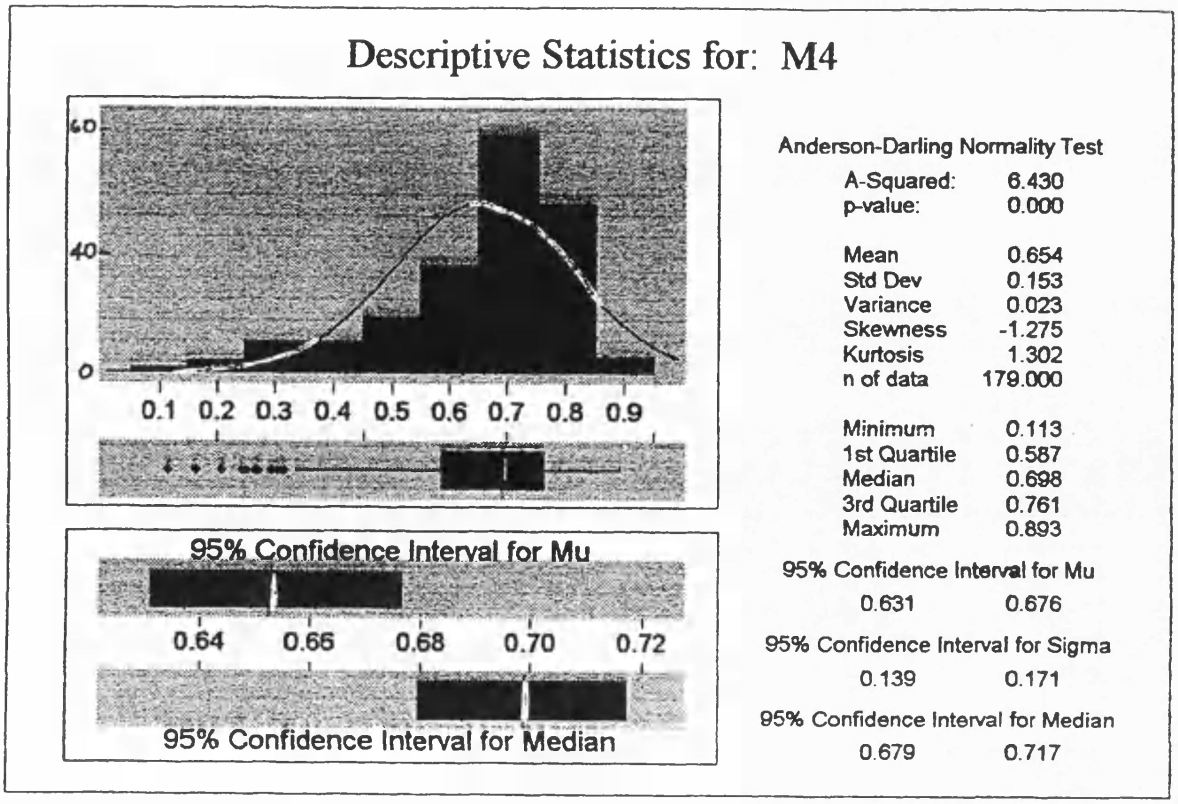
(b)


Descriptive Statistics for: M2
Anderson-Darling Normality Test
A-Squared: 4.717
p-value: 0.000
Mean 0.553
Std Dev 0.139
Variance 0.019
Skewness -1.161
Kurtosis 0.825
n of data 129.000
Minimum 0.108
1st Quartile 0.462
Median 0.601
3rd Quartile 0.643
Maximum 0.749
95% Confidence Interval for Mu
0.529 0.577
95% Confidence Interval for Sigma
0.124 0.158
95% Confidence Interval for Median
0.582 0.619
0.1 0.2 0.3 0.4 0.5 0.6 0.7
0.52 0.57 0.62
95% Confidence Interval for Mu
95% Confidence Interval for Median

(c)

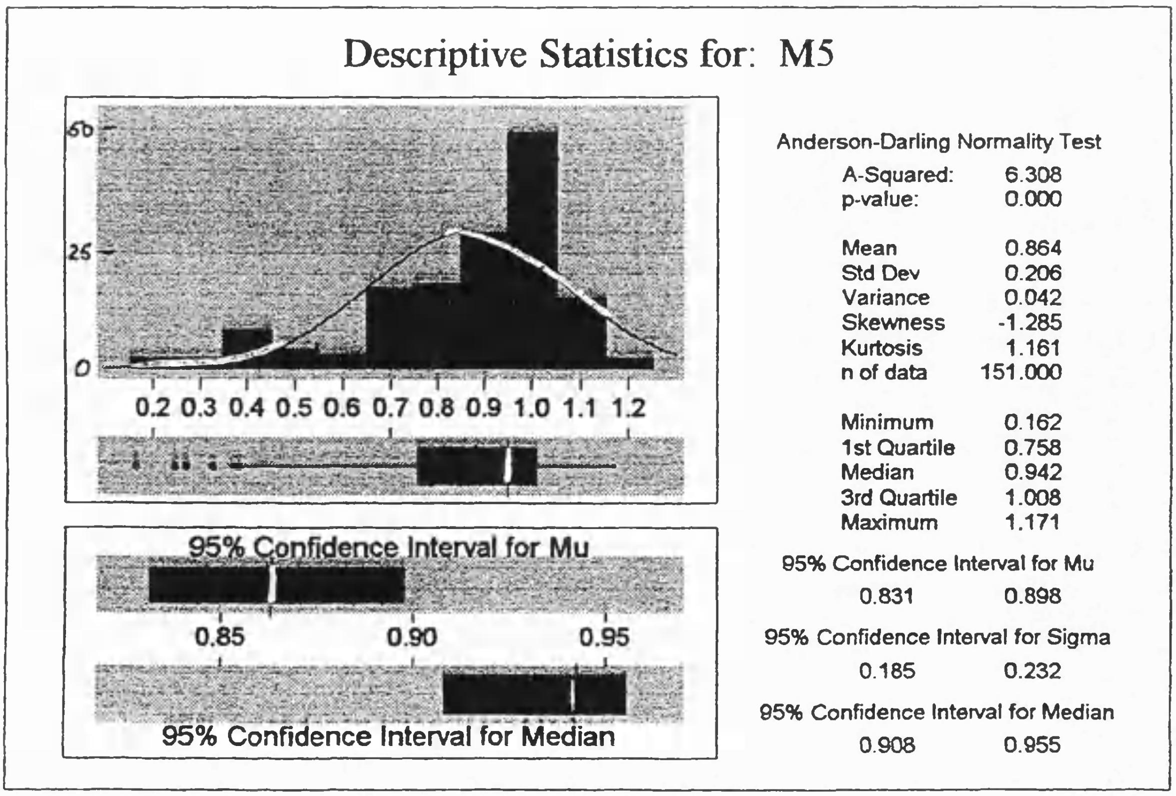

Descriptive Statistics for: M3
Anderson-Darling Normality Test
A-Squared: 9.388
p-value: 0.000
Mean 0.924
Std Dev 0.198
Variance 0.039
Skewness -2.000
Kurtosis 4.793
n of data 177.000
Minimum 0.090
1st Quartile 0.878
Median 0.963
3rd Quartile 1.031
Maximum 1.237
95% Confidence Interval for Mu
0.895 0.953
95% Confidence Interval for Sigma
0.179 0.221
95% Confidence Interval for Median
0.939 0.980
0.0 0.2 0.4 0.6 0.8 1.0 1.2
0.90 0.92 0.94 0.96 0.98
95% Confidence Interval for Mu
95% Confidence Interval for Median

(d)



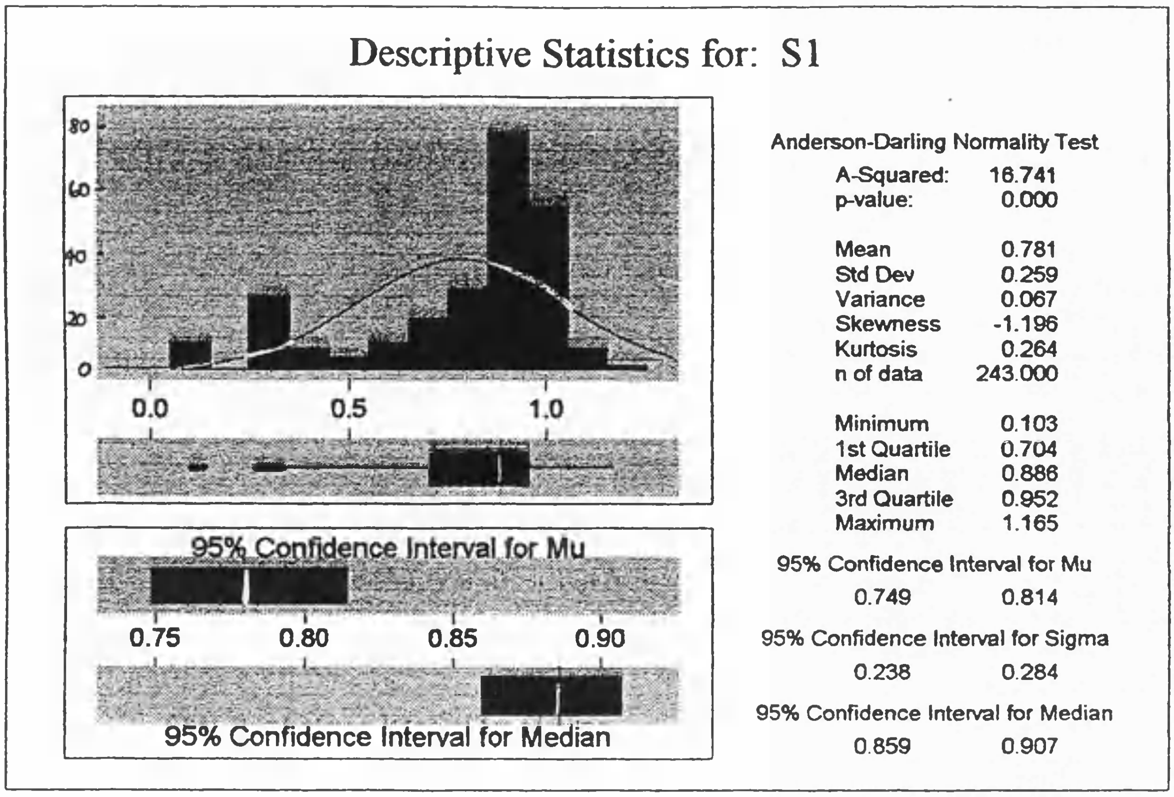
Descriptive Statistics for: M4
60
40
0
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9
95% Confidence Interval for Mu
0.64 0.66 0.68 0.70 0.72
95% Confidence Interval for Median
Anderson-Darling Normality Test
A-Squared: 6.430
p-value: 0.000
Mean 0.654
Std Dev 0.153
Variance 0.023
Skewness -1.275
Kurtosis 1.302
n of data 179.000
Minimum 0.113
1st Quartile 0.587
Median 0.698
3rd Quartile 0.761
Maximum 0.893
95% Confidence Interval for Mu
0.631 0.676
95% Confidence Interval for Sigma
0.139 0.171
95% Confidence Interval for Median
0.679 0.717

(e)

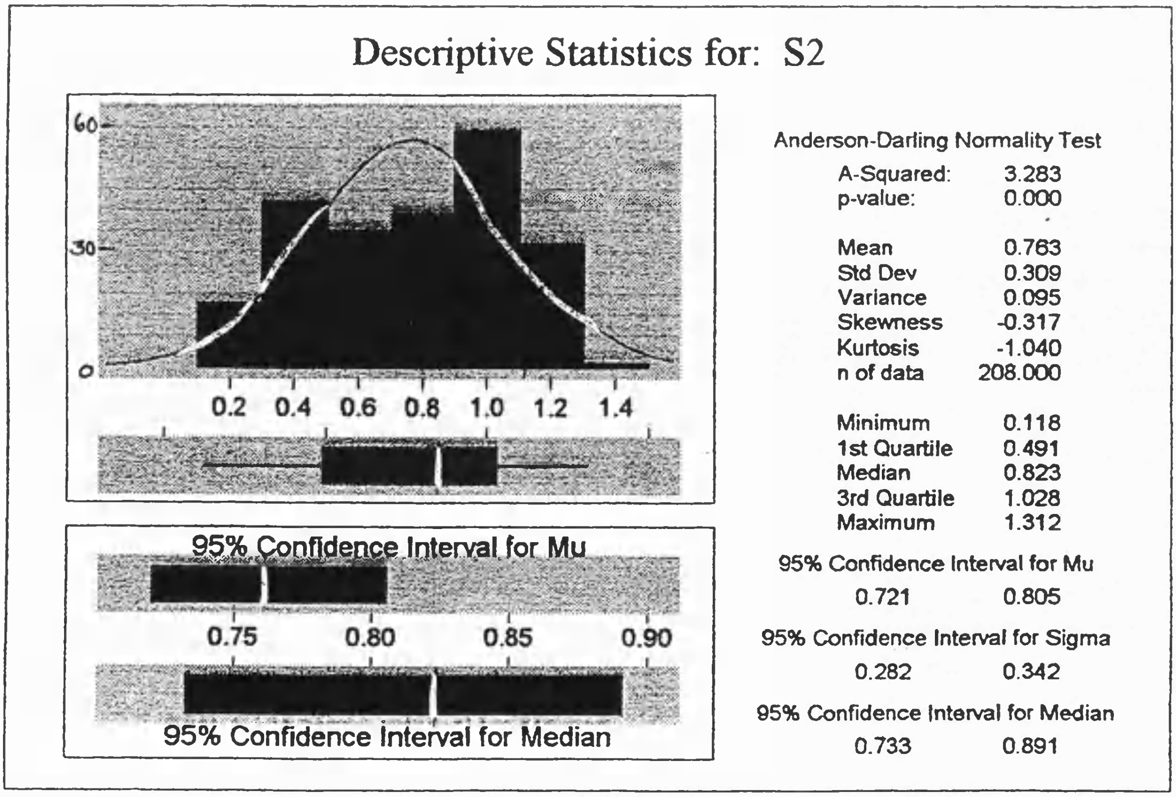


Descriptive Statistics for: M5
50
25
0
0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2
95% Confidence Interval for Mu
0.85 0.90 0.95
95% Confidence Interval for Median
Anderson-Darling Normality Test
A-Squared: 6.308
p-value: 0.000
Mean 0.864
Std Dev 0.206
Variance 0.042
Skewness -1.285
Kurtosis 1.161
n of data 151.000
Minimum 0.162
1st Quartile 0.758
Median 0.942
3rd Quartile 1.008
Maximum 1.171
95% Confidence Interval for Mu
0.831 0.898
95% Confidence Interval for Sigma
0.185 0.232
95% Confidence Interval for Median
0.908 0.955

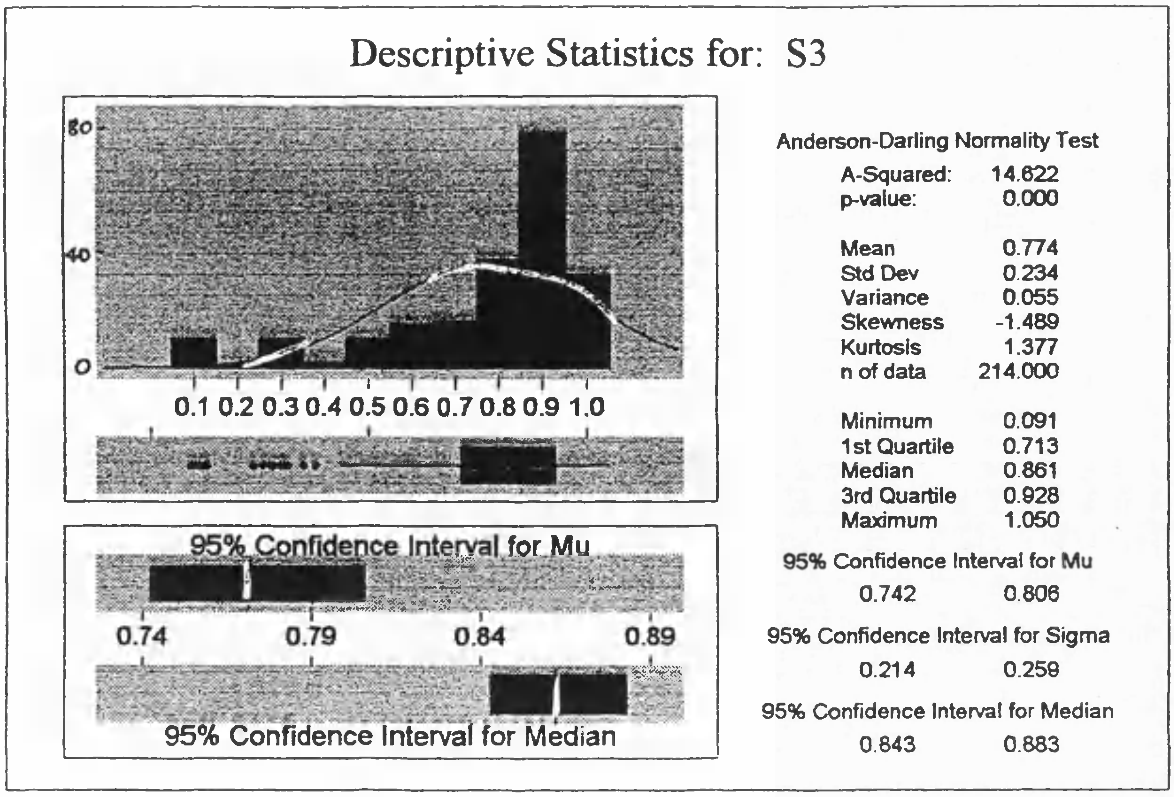
(f)


Descriptive Statistics for: S1
80
60
40
20
0
0.0
0.5
1.0
95% Confidence Interval for Mu
0.75
0.80
0.85
0.90
95% Confidence Interval for Median
Anderson-Darling Normality Test
A-Squared: 16.741
p-value: 0.000
Mean 0.781
Std Dev 0.259
Variance 0.067
Skewness -1.196
Kurtosis 0.264
n of data 243.000
Minimum 0.103
1st Quartile 0.704
Median 0.886
3rd Quartile 0.952
Maximum 1.165
95% Confidence Interval for Mu
0.749 0.814
95% Confidence Interval for Sigma
0.238 0.284
95% Confidence Interval for Median
0.859 0.907

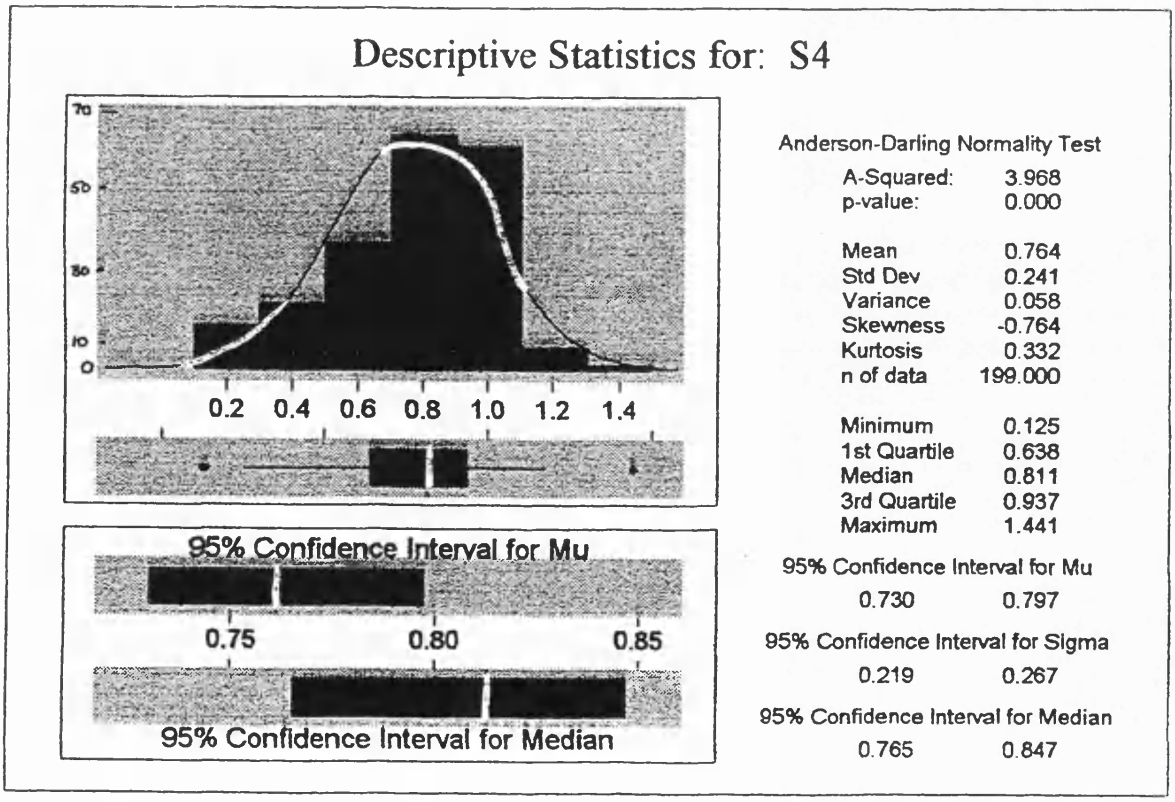
(g)


Descriptive Statistics for: S2
60
30
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
95% Confidence Interval for Mu
0.75
0.80
0.85
0.90
95% Confidence Interval for Median
Anderson-Darling Normality Test
A-Squared: 3.283
p-value: 0.000
Mean 0.763
Std Dev 0.309
Variance 0.095
Skewness -0.317
Kurtosis -1.040
n of data 208.000
Minimum 0.118
1st Quartile 0.491
Median 0.823
3rd Quartile 1.028
Maximum 1.312
95% Confidence Interval for Mu
0.721 0.805
95% Confidence Interval for Sigma
0.282 0.342
95% Confidence Interval for Median
0.733 0.891

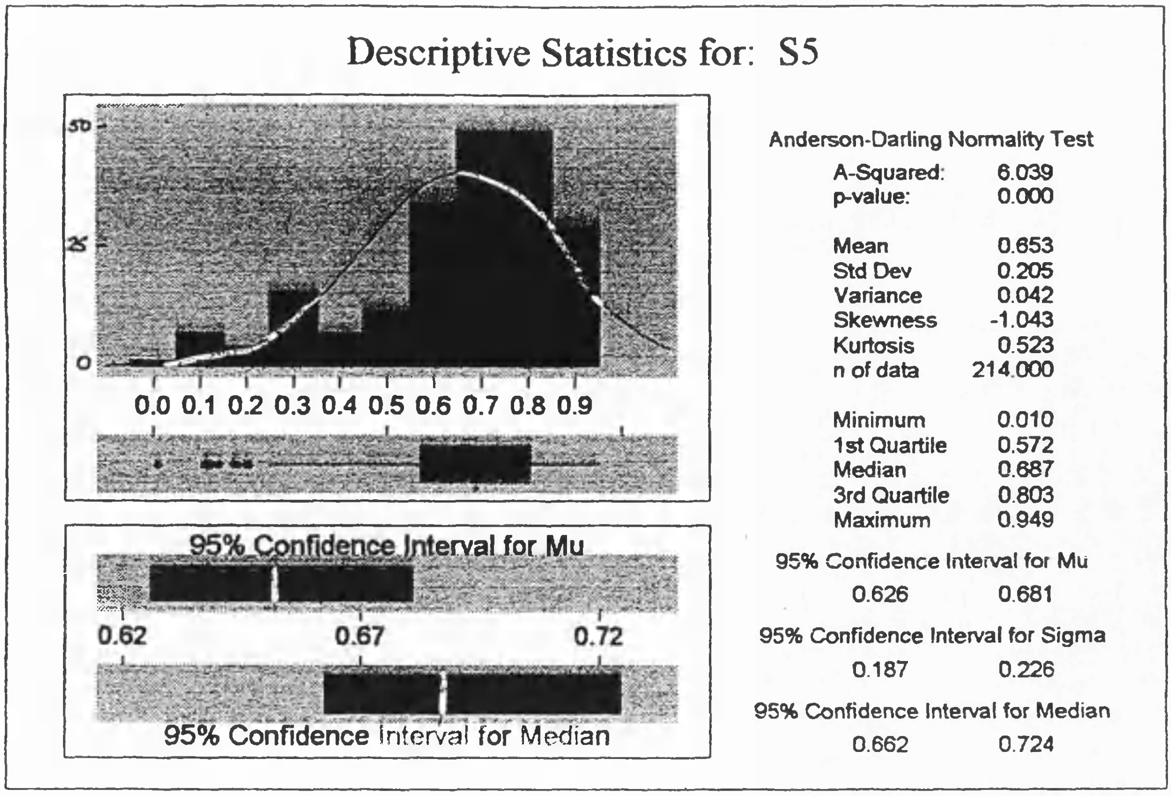
(h)


Descriptive Statistics for: S3
80
40
0
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
95% Confidence Interval for Mu
0.74 0.79 0.84 0.89
95% Confidence Interval for Median
Anderson-Darling Normality Test
A-Squared: 14.622
p-value: 0.000
Mean 0.774
Std Dev 0.234
Variance 0.055
Skewness -1.489
Kurtosis 1.377
n of data 214.000
Minimum 0.091
1st Quartile 0.713
Median 0.861
3rd Quartile 0.928
Maximum 1.050
95% Confidence Interval for Mu
0.742 0.806
95% Confidence Interval for Sigma
0.214 0.259
95% Confidence Interval for Median
0.843 0.883

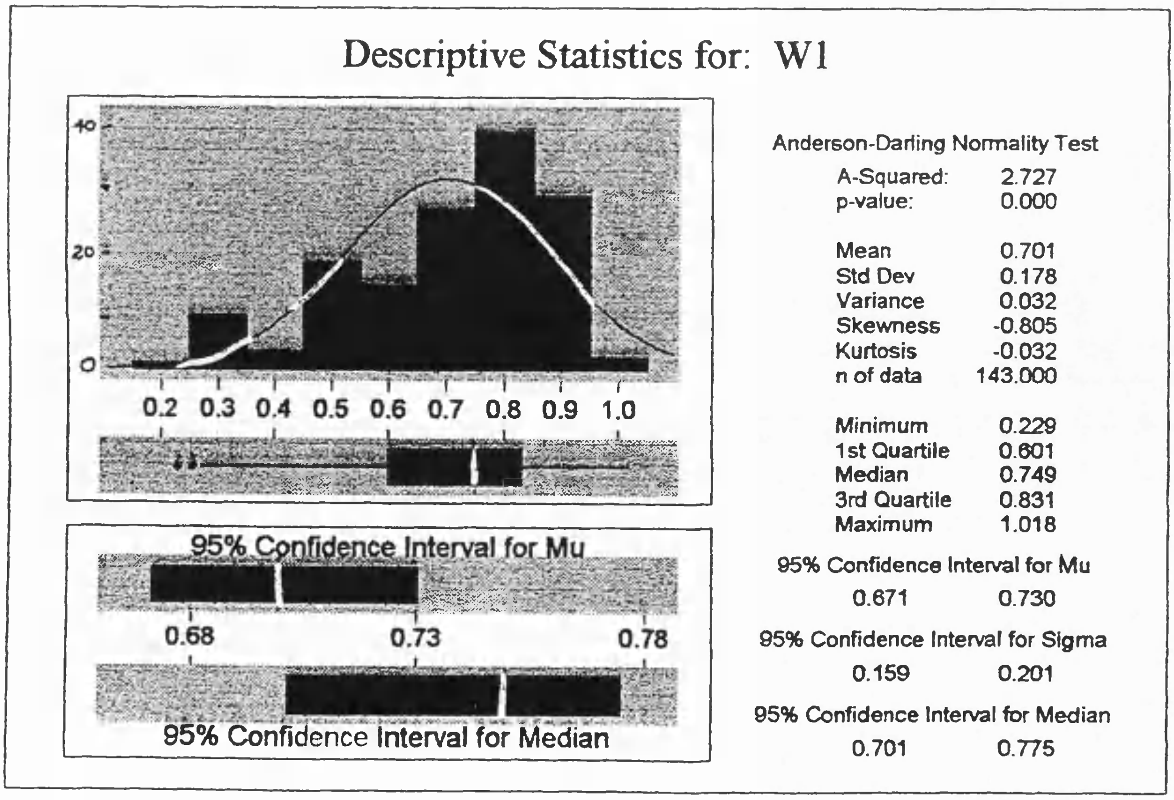
(i)


Descriptive Statistics for: S4
0.2 0.4 0.6 0.8 1.0 1.2 1.4
95% Confidence Interval for Mu
0.75 0.80 0.85
95% Confidence Interval for Median
Anderson-Darling Normality Test
A-Squared: 3.968
p-value: 0.000
Mean 0.764
Std Dev 0.241
Variance 0.058
Skewness -0.764
Kurtosis 0.332
n of data 199.000
Minimum 0.125
1st Quartile 0.638
Median 0.811
3rd Quartile 0.937
Maximum 1.441
95% Confidence Interval for Mu
0.730 0.797
95% Confidence Interval for Sigma
0.219 0.267
95% Confidence Interval for Median
0.765 0.847

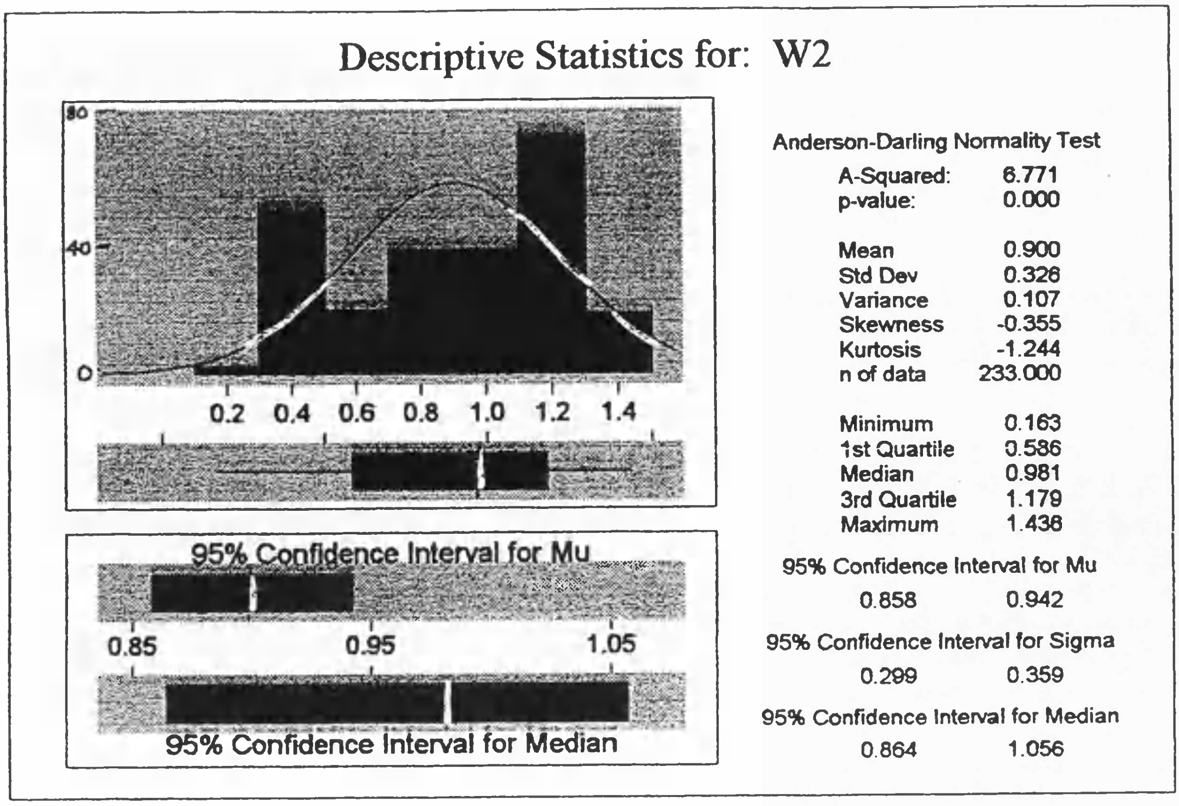
(j)


Descriptive Statistics for: S5
0
25
50
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9
95% Confidence Interval for Mu
0.62
0.67
0.72
95% Confidence Interval for Median
Anderson-Darling Normality Test
A-Squared: 6.039
p-value: 0.000
Mean 0.653
Std Dev 0.205
Variance 0.042
Skewness -1.043
Kurtosis 0.523
n of data 214.000
Minimum 0.010
1st Quartile 0.572
Median 0.687
3rd Quartile 0.803
Maximum 0.949
95% Confidence Interval for Mu
0.626 0.681
95% Confidence Interval for Sigma
0.187 0.226
95% Confidence Interval for Median
0.662 0.724

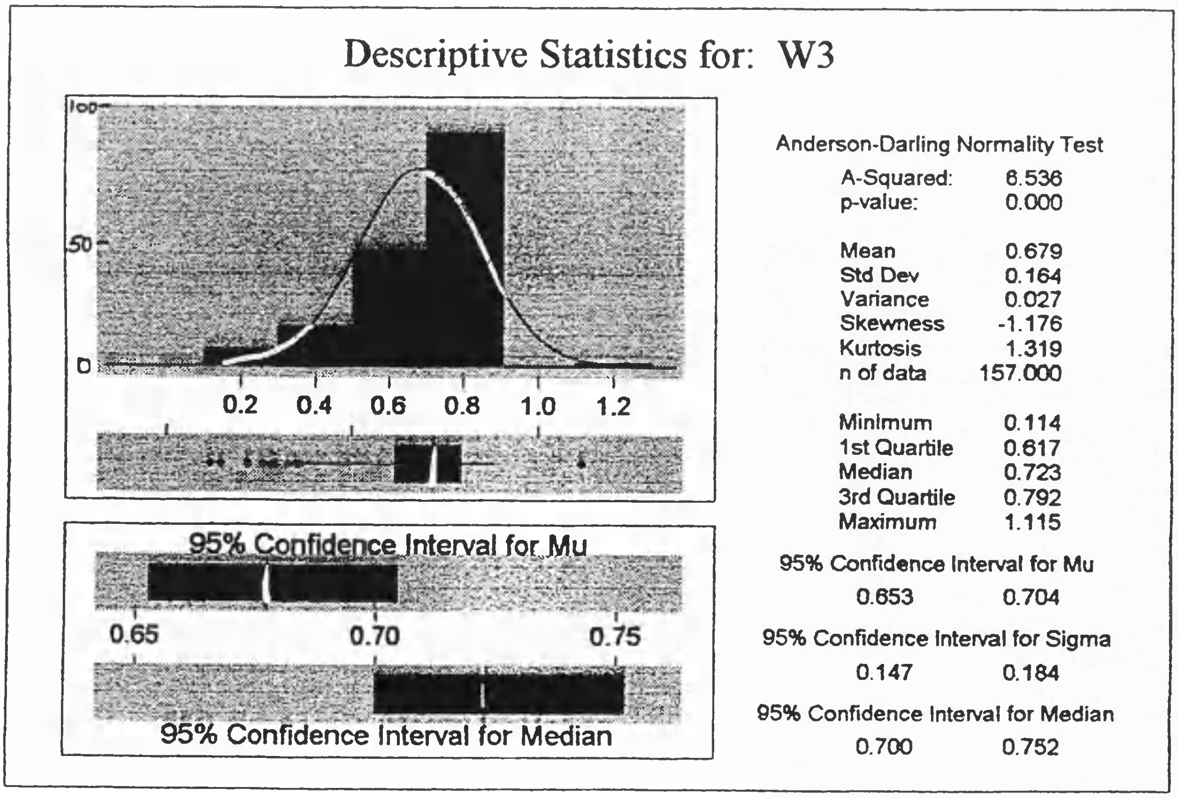
(k)


Descriptive Statistics for: W1
0
20
40
0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
95% Confidence Interval for Mu
0.68
0.73
0.78
95% Confidence Interval for Median
Anderson-Darling Normality Test
A-Squared: 2.727
p-value: 0.000
Mean 0.701
Std Dev 0.178
Variance 0.032
Skewness -0.805
Kurtosis -0.032
n of data 143.000
Minimum 0.229
1st Quartile 0.601
Median 0.749
3rd Quartile 0.831
Maximum 1.018
95% Confidence Interval for Mu
0.671 0.730
95% Confidence Interval for Sigma
0.159 0.201
95% Confidence Interval for Median
0.701 0.775

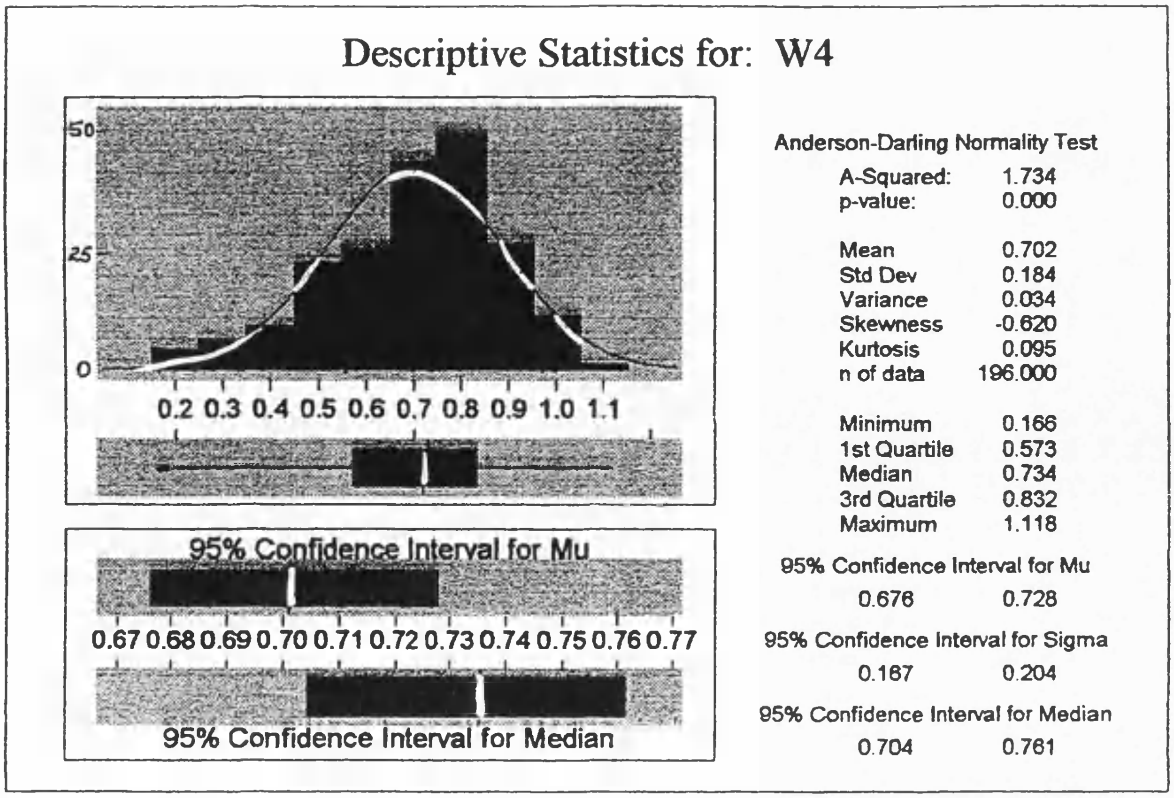
(l)


Descriptive Statistics for: W2
80
40
0
0.2 0.4 0.6 0.8 1.0 1.2 1.4
95% Confidence Interval for Mu
0.85 0.95 1.05
95% Confidence Interval for Median
Anderson-Darling Normality Test
A-Squared: 6.771
p-value: 0.000
Mean 0.900
Std Dev 0.326
Variance 0.107
Skewness -0.355
Kurtosis -1.244
n of data 233.000
Minimum 0.163
1st Quartile 0.586
Median 0.981
3rd Quartile 1.179
Maximum 1.436
95% Confidence Interval for Mu
0.858 0.942
95% Confidence Interval for Sigma
0.299 0.359
95% Confidence Interval for Median
0.864 1.056

(m)


Descriptive Statistics for: W3
100
50
0
0.2 0.4 0.6 0.8 1.0 1.2
95% Confidence Interval for Mu
0.65 0.70 0.75
95% Confidence Interval for Median
Anderson-Darling Normality Test
A-Squared: 6.536
p-value: 0.000
Mean 0.679
Std Dev 0.164
Variance 0.027
Skewness -1.176
Kurtosis 1.319
n of data 157.000
Minimum 0.114
1st Quartile 0.617
Median 0.723
3rd Quartile 0.792
Maximum 1.115
95% Confidence Interval for Mu
0.653 0.704
95% Confidence Interval for Sigma
0.147 0.184
95% Confidence Interval for Median
0.700 0.752

(n)


Descriptive Statistics for: W4
Anderson-Darling Normality Test
A-Squared: 1.734
p-value: 0.000
Mean 0.702
Std Dev 0.184
Variance 0.034
Skewness -0.620
Kurtosis 0.095
n of data 196.000
Minimum 0.166
1st Quartile 0.573
Median 0.734
3rd Quartile 0.832
Maximum 1.118
95% Confidence Interval for Mu
0.676 0.728
95% Confidence Interval for Sigma
0.167 0.204
95% Confidence Interval for Median
0.704 0.761
0 25 50
0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1
0.67 0.68 0.69 0.70 0.71 0.72 0.73 0.74 0.75 0.76 0.77

(o)

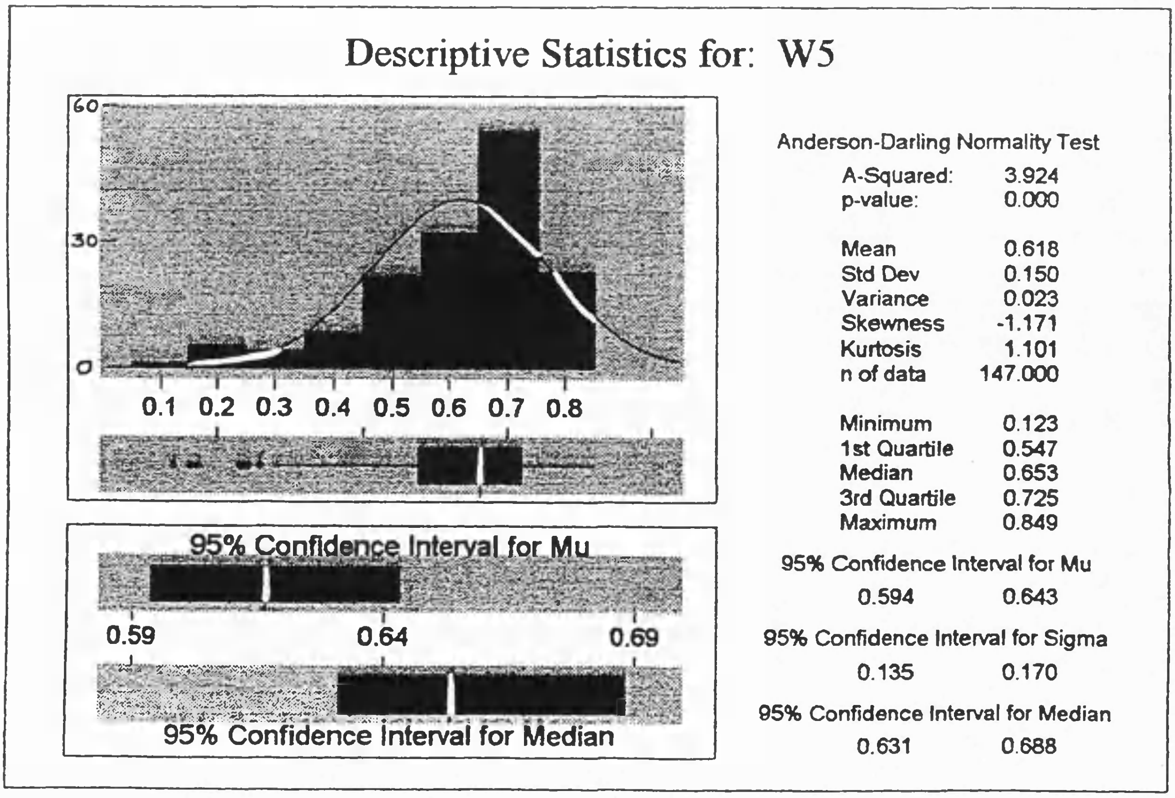

Descriptive Statistics for: W5
Anderson-Darling Normality Test
A-Squared: 3.924
p-value: 0.000
Mean 0.618
Std Dev 0.150
Variance 0.023
Skewness -1.171
Kurtosis 1.101
n of data 147.000
Minimum 0.123
1st Quartile 0.547
Median 0.653
3rd Quartile 0.725
Maximum 0.849
95% Confidence Interval for Mu
0.594 0.643
95% Confidence Interval for Sigma
0.135 0.170
95% Confidence Interval for Median
0.631 0.688
0 30 60
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8
0.59 0.64 0.69

Table 1:

Summary of distribution of achene weight (mg) of initial material from three locations.

M1-5 are capitula collected from the meadow location, S1-5 are capitula from the 'ski-slope' and W1-5 are capitula from the wall location.

Capitulum	Number of achenes	Mean wt of achenes + std. dev.
M1	136	0.742+0.16
M2	129	0.553+0.14
M3	177	0.924+0.20
M4	179	0.654+0.15
M5	151	0.864+0.21
S1	243	0.781+0.26
S2	208	0.763+0.31
S3	214	0.774+0.23
S4	199	0.764+0.24
S5	214	0.653+0.21
W1	143	0.701+0.18
W2	233	0.900+0.33
W3	157	0.679+0.16
W4	196	0.702+0.18
W5	147	0.618+0.15

It can be seen from Figure 1 and Table 1 that there is a great deal of variation in the data, with clones from the M location generally having the fewest achenes per capitulum and those from the S location generally having most. Likewise the range of weights shows variation from a minimum of approximately 0.1mg (except in W1 where the minimum is 0.229mg) to a maximum of between 0.749mg - 1.441mg. The frequency distribution curves show a skewness to the left for all clones. In all 15 frequency distributions the mean and median do not coincide. Twelve of the curves are leptokurtic (i.e. have more weights near the mean and at the tails with fewer weights in the intermediate regions relative to a normal distribution with the same mean and variance). S2, W1 and W2 have curves which are platykurtic (i.e.with fewer weights at the mean and the tails than the normal curve, but more weights in the intermediate regions). The Anderson-Darling test results printed alongside the distribution histograms in figure 1 (a-o) provide strong evidence for a non-normal distribution ($p < 0.001$). (The higher the A^2 value the stronger the evidence for a non-normal distribution.) All 15 clones show a tendency to a non-normal distribution, but especially M3, S1 and S3.

2.1.2 Germination of Initial Material

2.1.2(a) Materials and Methods

All achenes collected for each of the 15 clones, except for those that were clearly non-viable (i.e. empty achenes which appear lighter in colour and more pliable than those containing an embryo) were sown on the surface of the 'M1 Levington' compost in individually labelled compartments of seed trays. The trays were placed on a heated greenhouse bench under a mist unit. A minimum temperature of 11^{0}C was maintained in the greenhouse and the mist unit was controlled by an electronic probe. Germination assessments were made daily until no germination had occurred for 14 consecutive days, after which the experiment was terminated. Achenes were considered to have germinated when the cotyledons had appeared above the level of the compost.

2.1.2(b) Results

Germination was erratic, with overall percentage germination ranging from 4.8% to 86.0%. Germination of achenes weighing less than 0.4mg was particularly poor, with only 6 germinating from 205 sown. For most clones a germination rate above 50% was observed only for achenes weighing over 0.8mg. However, in clone W5 germination was particularly poor, with only 7 achenes germinating out of a total of 147 sown. A summary of the germination results of this initial material is given in Table 2, (a-c).

Table 2:

The germination (numbers) of initial material, grouped according to weight of achene (mg).

The achenes from each capitulum have been grouped into classes according to weight. The number in each class and the number germinated are given. *

(a)

Clones collected from site M:

Wt. in mg	M1		M2		M3		M4		M5	
up to	No.	Germ.	No.	Germ.	No.	Germ.	No.	Germ.	No.	Germ.
0.3	3	0	5	1	2	0	6	1	2	0
0.4	5	3	8	0	4	0	8	0	6	0
0.5	2	1	21	9	2	1	9	2	3	0
0.6	8	3	26	7	1	1	21	2	4	1
0.7	12	12	54	10	2	0	44	3	11	1
0.8	45	40	11	1	12	7	71	10	18	9
>0.8	60	59			151	121	18	6	106	92
N/V	1		4		3		2			

* N/V indicates number non-viable.

(b)

Clones collected from site W:

Wt. in mg	W1		W2		W3		W4		W5	
up to	No.	Germ.	No.	Germ.	No.	Germ.	No.	Germ.	No.	Germ.
0.3	8	0	0	0	4	0	2	0	6	0
0.4	3	0	8	0	10	0	10	0	6	2
0.5	9	3	41	0	5	1	10	3	10	3
0.6	15	5	8	1	16	3	31	21	30	2
0.7	25	22	11	5	29	8	27	17	38	0
0.8	37	31	19	11	58	9	49	37	48	0
>0.8	46	45	144	120	33	12	64	58	6	0
N/V	0		2		2		3		3	

(c)

Clones collected from site S:

Wt. in mg	S1		S2		S3		S4		S5	
up to	No.	Germ.	No.	Germ.	No.	Germ.	No.	Germ.	No.	Germ.
0.3	9	0	5	0	7	0	6	0	6	0
0.4	22	0	16	0	5	0	10	1	13	0
0.5	4	2	23	0	8	6	8	3	7	3
0.6	3	2	15	1	12	10	11	9	23	16
0.7	13	10	17	1	9	8	24	23	53	34
0.8	28	25	15	5	24	22	31	31	46	33
>0.8	155	151	107	90	139	138	104	102	55	43
N/V	9		10		10		6		11	

2.1.2(c) Discussion

It is not clear which factors determine whether or not an achene will germinate and by what mechanism loss of viability occurs (Roberts 1979). Seeds go through a series of changes before they finally lose viability. Almost every system in the seed is involved with the loss of viability: many enzymes and apparently all organelles are affected (Roberts 1979). Roberts (1979) states that loss of viability is preceded by slower potential rates of germination and seedling growth - attributes which are often associated with 'vigour'. Certainly, some of the achenes took much longer to germinate than others: 15-20 days from sowing to germination were recorded for some achenes, compared with an average period of 6 days. Roberts (1979) also states that it is clear that the process of seed deterioration starts before seed is put into storage, probably as soon as the seed is first formed, and that various factors appear to affect the initial quality of seed which, in turn, affects storage potential.

The loss of viability, particularly of lighter achenes, may have been due to storage conditions during the period between harvesting and the commencement of these experiments, an interval of approximately 5 months. This will be explored later with experiments designed to look at the viability of achenes, sorted into classes according to weight, over a period of a year (see Chapter 3).

2.2 The Pre-germination Stage and Relationships between Achene, Achene Coat and Embryo Weights.

2.2.1 Introduction.

In many plant populations, high mortality characterises the seed and seedling stage. Studies have indicated that among the progeny of an individual, those developed in larger seeds are much more likely to survive the seed and seedling stage than those that have developed in smaller seeds (Schaal 1980; Morse and Schmitt 1985). It appears that for many species, heavier achenes/seeds are more likely than lighter ones to germinate and, because of a proportionally larger allocation to the embryo, heavier achenes/seeds will germinate earlier and produce larger, more competitive seedlings than lighter achenes/seeds (Fenner 1985; Prinzie and Chmielewski 1994).

In the following subsection, an investigation of the relationship between achene and embryo weight in *Taraxacum* is described.

2.2.2 Materials and Methods.

The fresh weights of each of 100 achenes from each of 6 clones of *Taraxacum* (M1,M2,W1,W3,W5,S3) were determined to 0.0001mg using a Mettler UMT2 microbalance. These achenes were derived from plants grown from the initial material described in the previous section. For example, M1 achenes came from plants grown from the M1 initial material. These original achenes had been germinated and the plants grown to maturity and the resulting achenes collected. (Each batch of 100 came from a single capitulum of a plant grown in bare soil at the University of Bath Field Station at Bathampton. The pappus was removed prior to weighing.) For ease of handling, achenes were arbitrarily split into batches of 25 before dissection.

Following Sheppard (1993) the labelled achenes were soaked in distilled water for 24h in individual cells of a 25 cell petri dish. Soaking softens the achenes, making their dissection easier. Holding the shoulder of the achene with tweezers, each achene was split longitudinally using a fine scalpel. The intact embryo was carefully removed. The embryo and achene coat were individually wrapped in aluminium foil, labelled and dried in an oven at 80^0 C for 24h. After cooling to room temperature, the foil packages were weighed both with and without their contents. The dry weights of both embryos and achene coats were calculated by subtraction. A summary of these weights is given in Figure 2 i-vi (a).

2.2.3 Results

For each of the six clones, a regression was performed (using Minitab Statistics software) to establish whether any significant relationship existed between achene coat dry weight and embryo dry weight. The mean proportion of total dry weight allocated to achene embryos is summarised in Tables 3 -8 (a), along with the regression equations in Tables 3 -8 (b). Bar charts (Figures 2 - 7) present the data graphically.

The regressions for M1, M2, W1 and W3 are all significant. The coefficient of determination (r^2) varies from 0.411 for M1 to 0.01 for W5. This coefficient indicates that, in M1, just over 41% of the variation in embryo dry weight is explained by variation in the achene coat dry weight, but this decreases to 1% in W5.

From Tables 3 - 8 (a) it can be seen that the proportion of total achene weight allocated to the embryo increases with increasing achene fresh weight. This is also shown in Figures 2 - 7. The weights of both achene coat and embryo appear to increase independently of one another. Taking the minimum and maximum achene coat and embryo dry weights, the increase (in orders of magnitude) is summarised in Table 9. In all 6 clones studied, the increase in weight is greater for embryo dry weight than for achene coat dry weight.

Table 3

Proportion of total dry weight allocated to achene embryos for M1.

(a)

Achene fresh weight (mg) up to:	Proportion	Achene coat dry weight (mg)	Embryo dry weight (mg).
0.4	0.54	0.17	0.18
0.6	0.49	0.26	0.25
0.7	0.49	0.27	0.26
0.8	0.52	0.31	0.34
0.9	0.58	0.32	0.44
1.2	0.55	0.49	0.6
1.3	0.56	0.51	0.65
1.4	0.55	0.55	0.67
1.5	0.6	0.55	0.82

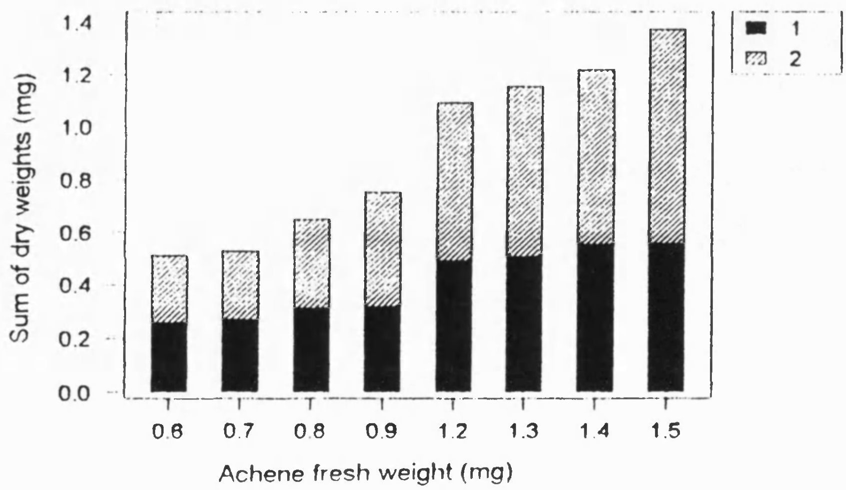
(b) Regression equation for embryo dry weight versus achene coat dry weight:

Embryo dwt = 0.0323 + 1.5904 (achene coat dwt) $r^2 = 0.411$

Anova: $F = 67.58$ $p = 0.000$

Figure 2

Comparison of achene weight with achene coat/embryo dry weight for M1



Where 1=seed coat dwt and 2=embryo dwt.

Table 4

Proportion of dry weight allocated to achene embryos for M2.

(a)

Achene fresh weight (mg) up to:	Proportion	Achene coat dry weight (mg)	Embryo dry weight (mg).
0.3	0.26	0.17	0.06
0.4	0.29	0.23	0.07
0.5	0.35	0.26	0.14
0.6	0.45	0.26	0.22
0.7	0.48	0.3	0.27
0.8	0.5	0.34	0.34
0.9	0.53	0.37	0.41
1	0.46	0.48	0.38

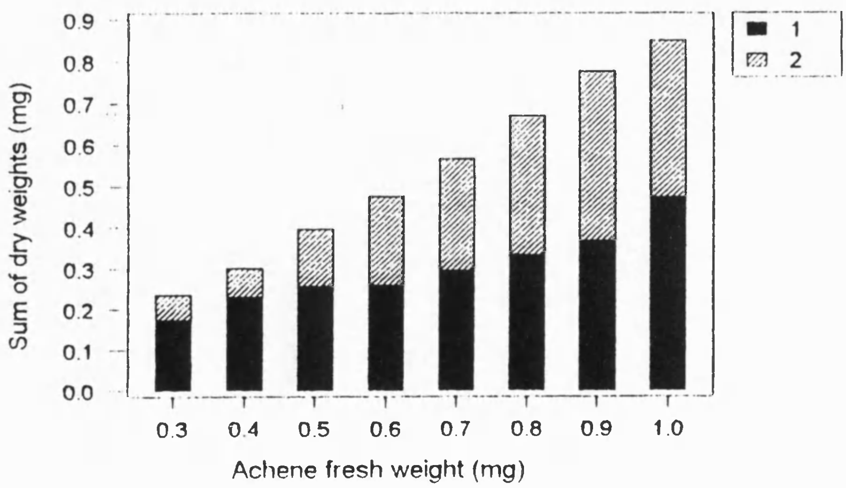
(b) Regression equation for embryo dry weight versus achene coat dry weight:

Embryo dwt = 0.0942 + 0.528 (achene coat dwt) $r^2 = 0.124$

Anova: $F = 12.99$ $p = 0.001$

Figure 3

Comparison of achene weight with achene coat/embryo dry weight for M2



Where 1=seed coat dwt and 2= embryo dwt.

Table 5

Proportion of dry weight allocated to achene embryos for W1

(a)

Achene fresh weight (mg) up to:	Proportion	Achene coat dry weight (mg).	Embryo dry weight (mg)
0.3	0.18	0.18	0.04
0.4	0.23	0.23	0.07
0.5	0.33	0.25	0.13
0.6	0.37	0.29	0.17
0.7	0.4	0.33	0.22
0.8	0.48	0.32	0.3
0.9	0.51	0.36	0.37
1	0.53	0.38	0.42
1.1	0.61	0.37	0.58

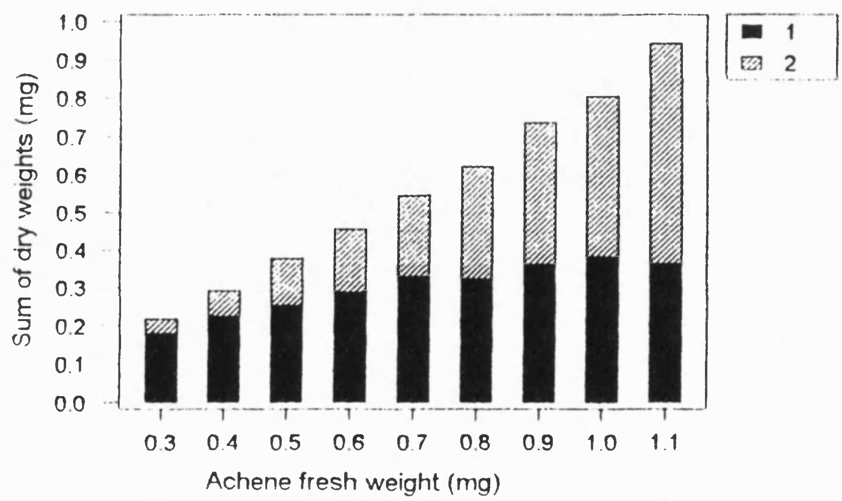
(b) Regression equation for embryo dry weight versus achene coat dry weight:

Embryo dwt = 0.0551 + 0.574 (achene coat dwt) $r^2 = 0.101$

Anova: $F = 11.72$ $p = 0.001$

Figure 4

Comparison of achene weight with achene coat/embryo dry weight for W1



Where 1=seed coat dwt and 2= embryo dwt.

Table 6

Proportion of dry weight allocated to achene embryos for W3

(a)

Achene fresh weight (mg) up to:	Proportion	Achene coat dry weight (mg)	Embryo dry weight (mg)
0.3	0.14	0.18	0.03
0.4	0.39	0.18	0.11
0.5	0.44	0.21	0.16
0.6	0.52	0.22	0.24
0.7	0.6	0.24	0.36
0.8	0.51	0.29	0.31

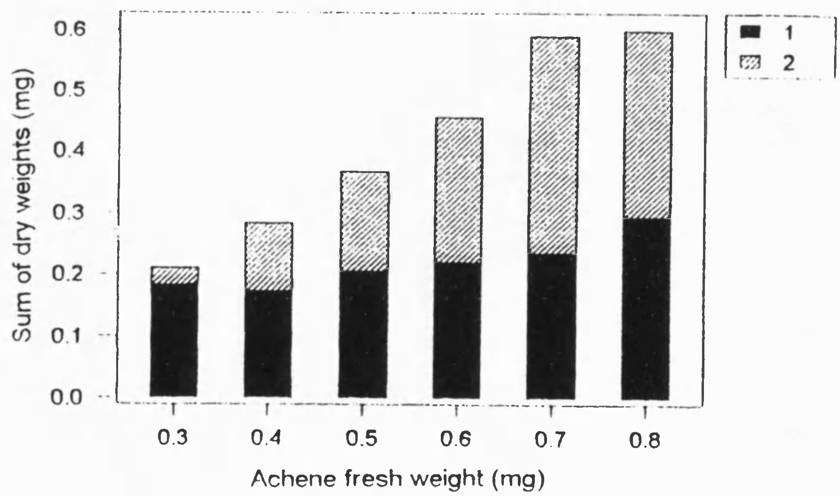
(b) Regression equation for embryo dry weight versus achene coat dry weight:

Embryo dwt = 0.0438 + 0.878 (achene coat dwt) $r^2 = 0.091$

Anova: $F = 9.41$ $p = 0.003$

Figure 5

Comparison of achene weight with achene coat/embryo dry weight for W3



Where 1=seed coat dwt and 2= embryo dwt.

Table 7

Proportion of dry weight allocated to achene embryos for W5

(a)

Achene fresh weight (mg) up to :	Proportion	Achene coat dry weight (mg)	Embryo dry weight (mg)
0.3	0.29	0.17	0.07
0.4	0.52	0.17	0.19
0.5	0.55	0.19	0.23
0.6	0.59	0.2	0.29
0.7	0.6	0.23	0.34
0.8	0.6	0.26	0.39
0.9	0.65	0.28	0.51

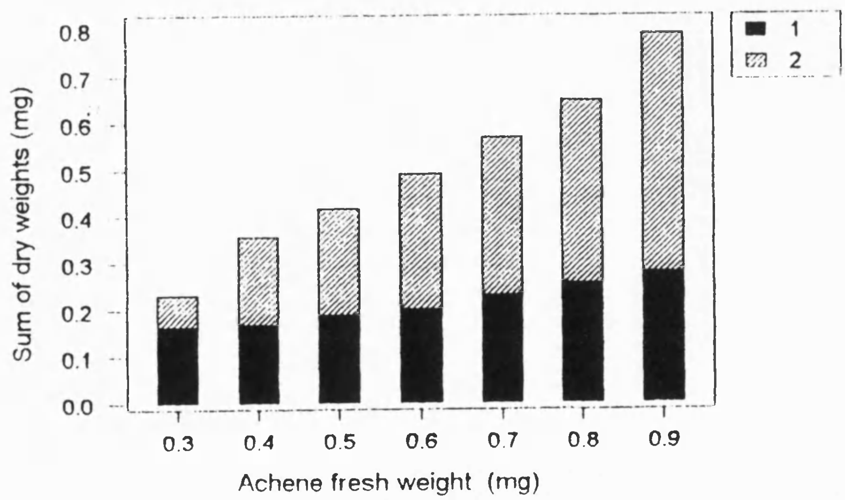
(b) Regression equation for embryo dry weight versus achene coat dry weight:

Embryo dwt = 0.29 + 0.079 (achene coat dwt) $r^2 = 0.01$

Anova: $F = 0.12$ $p = 0.727$

Figure 6

Comparison of achene weight with achene coat/embryo dry weight for W5



Where 1=seed coat dwt and 2= embryo dwt.

Table 8

Proportion of dry weight allocated to achene embryos for S3

(a)

Achene fresh weight (mg) up to:	Proportion	Achene dry weight (mg)	Embryo dry weight (mg)
0.5	0.46	0.21	0.18
0.6	0.5	0.25	0.25
0.7	0.57	0.25	0.33
0.8	0.61	0.27	0.42
0.9	0.61	0.3	0.46
1	0.64	0.32	0.55

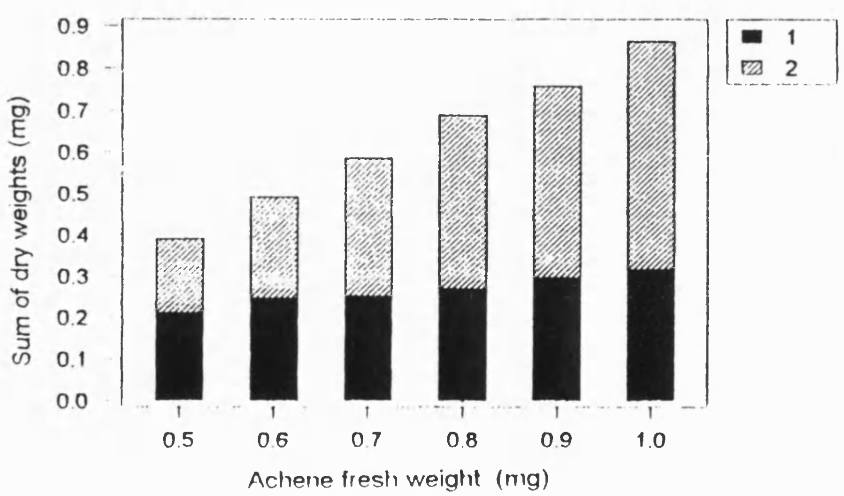
(b) Regression equation for embryo dry weight versus achene coat dry weight:

Embryo dwt = 0.289 + 0.42(achene coat dwt) $r^2 = 0.03$

Anova: $F = 3.14$ $p = 0.08$

Figure7

Comparison of achene weight with achene coat/embryo dry weight for S3



Where 1=seed coat dwt and 2= embryo dwt

Table 9

Taraxacum clones; analysis of achene coat/embryo dry weight variation by taking the minimum and maximum dry weights of achene coats and embryos.

Clone	Variation (x fold)	Coeff of variation (%)
M1 coat dwt	3.6	30.9
embryo dwt	10.8	44.6
M2 coat dwt	4.3	24.4
embryo dwt	18.2	43.3
W1 coat dwt	6.0	32.6
embryo dwt	97.0	77.2
W3 coat dwt	5.3	18.9
embryo dwt	120	51.1
W5 coat dwt	3.8	23.8
embryo dwt	21.3	37.1
S3 coat dwt	3.2	16.1
embryo dwt	5.6	24.9

2.2.4 Discussion

The results show that in 4 of the 6 clones studied there is a significant positive association in the variation of embryo and achene coat dry weights. It is reasonable to conclude from this that a similar association also exists in the variation of embryo and achene coat fresh weights. (It is impossible to measure the fresh weight of these two components directly as soaking prior to dissection is necessary). In brief, heavier achenes contain larger embryos. As total achene weight increases, the weights of both components increases, with embryo weight showing a higher rate of increase than achene coat weight.

From the large amount of weighing performed during this research, it was found that achenes which were empty in the mature capitulum weigh approximately 0.1 mg (fresh weight). Achene coats from achenes which contained an embryo, however small, were never lighter than this. It can be suggested that once achenes are initiated, resources available for reproduction dictate the number of embryos matured and hence the number of achenes that are filled and their subsequent size. Thus Lloyd (1989), has suggested that 'for an intermediate number of seeds (neither one nor infinity) to be the parental optimum, the fitness curve relating the success of individual seeds to their size must at first decrease slowly or not at all and then increase rapidly before the rate of increase declines again.' In other words, seeds have no chance of survival until they reach a minimum size (S_m). This minimum size might be imposed by the fixed costs of seed coats or by the lack of competitive ability of smaller seeds. The fitness of individual offspring is assumed to be proportional to their size beyond the minimum, raised to a power, x. When the fitness of the parent plant is proportional to the number of offspring it produces, Lloyd (1989), gives a constrained optimum for parents at: $S = \frac{S_m}{1-x}$,

where S = ESS (Evolutionarily Stable Strategy), S_m = minimum size,

and x = a power, where marginal fitness of increasing size and number are equated.

Lloyd (1989) suggests that optimal size does not depend on the amount of parental resources; instead variation in resources should be tracked by variation in offspring number, not by variation in seed size (this was first noted by Salisbury 1942). In *Taraxacum*, variation in the number of achenes per capitulum may be a reflection of parental resources at the time of ovule initiation. But why do achenes vary in weight, and why do capitula have different weight ranges? Lloyd's (1989) model indicates that the size of offspring at seed maturity is related to the size at which they can 'procure food' (Ito 1980) or more generally, become 'durable' in their natural environment (Lloyd 1987). It also helps to explain correlations between the size of offspring at seed maturation and various parameters such as k-strategies, parental size and physically demanding habitats for juveniles. But, as shown by Harper, Lovell and Moore (1970), a high degree of constancy of seed size is often maintained over an extremely wide range of intraspecific plant densities, but less so over interspecific plant densities. The constancy of seed weight also seems to be a feature of species in which the terminal meristems are not used up in flowering and in which the vigour of a plant is positively correlated with the number of its parts (Harper *et al.* 1970). However, in many of Harper's *et al.* (1970) examples, the observed constancy was in mean seed weight from pooled intraspecific samples; thus any variation in seed weight among mothers or within 'broods' was obscured. Variation between mothers in mean seed weight need not invalidate the model of optimum seed size. The variation may be environmental or genetic. If environmental, it is possible that the variation is an adaptive reponse to changes in the seed provisions/survival relationship (Haig and Westoby 1988). Variation in mean seed weight among the broods of a mother could have a similar explanation, as Temme (1986), has shown that Smith and Fretwell's model (Smith and Fretwell 1974) predicts variation in seed size if mothers are able to detect differences in offspring quality.

From the results obtained with the *Taraxacum* clones, it appears that in 4 cases (M1,M2,W1 and W3) the variation between achene coat and embryo continues to maturity.

All achenes dissected were from mature capitula. Ovules are initiated at the base of the embryonic flower bud, with the number initiated being dictated by parental resources available at that time. If maternal resources are divided equally between these ovules, the weight of newly initiated achenes should be the same. Achene coat weight will increase if the ovule contains an embryo. It will continue to increase towards an upper limit in order to accommodate the growing embryo. The data summarised in Figures 2 - 7 indicate that the pattern of provision of maternal resources to an achene coat is usually correlated with that to the achene's embryo, so that heavier embryos are usually enclosed within heavier achene coats.

However, the absence of statistically significant associations between achene coat weight in two of the clones, and the low coefficients of determination in the others, indicate that the pattern of provisioning is complex. There is no evidence that it is optimal. It is important to recognise that *Taraxacum* apomicts are polyploid and that many are also hybrids, and that both polyploidisation and hybridisation can disrupt physiological processes, including patterns of resource allocation according to Mogie (1992). A comparison of the pattern of maternal provisioning to achene coats and embryos in diploid sexuals and polyploid apomicts would provide useful information on whether a switch from obligately sexual to apomictic reproduction results in a disruption of the pattern of resource allocation to achenes. This was beyond the scope of this study.

Chapter 3

In this chapter is described an investigation into the relationship between achene weight and viability. Its aim is to establish the role played by both in germination. It reports on the investigation of the effects that the age of achenes has on germination and concludes with a description of the germination of excised embryos *in vitro.*

3.1.1 Introduction

Following from the observations of the erratic germination of the initial experimental material (chapter 2, section 2.1.2) it was decided to conduct further experiments over a period of a year to assess the relationship between achene size and viability.

It is now well established that, for seeds of most species, viability is prolonged if they are stored at low temperature and with a low moisture content (Roberts 1979). However, it is still not clear which factors are critical for the maintainance of viability, and by what mechanism loss of viability occurs. Seeds go through a series of changes before they lose viability. The causes of this loss may be divided into two categories: extrinsic and intrinsic (Roberts 1979). Extrinsic causes include pathogens and ionising radiation. However, it is now clear (Roberts 1979) that although extrinsic factors can contribute to a loss of viability, they are rarely a major cause or the sole cause of a loss of viability. Intrinsic causes include a loss of biochemical integrity. This can result in an accumulation of toxic metabolites, in damage brought about by free-radical production (primarily to the lipids of the cell membranes) or in the denaturing of large molecules (the rate of which is dependent on the temperature and moisture content of the seed) (Roberts 1979).

Whatever causes the loss of viability, it is clear that this loss is preceded by a reduction in the rate of germination and in the rate of seedling growth. This process of seed deterioration is thought to be initiated immediately after the seed is formed (Roberts 1979).

3.1.1(a) Germination Tests

A laboratory germination test identifies the percentage of seeds which are capable of producing viable seedlings under standardised conditions. The substrate, moisture supply and temperature must be standardised, and the assessment of seedlings must be carried out at a stage of their development at which their condition can be accurately evaluated.

The principal environmental requirements for seed germination are an adequate water supply, a suitable temperature and a suitable composition of gases in the atmosphere. These vary according to species and are determined in part by conditions which prevailed during seed formation and in part by hereditary factors (Mackay, in Roberts 1972). In addition, seeds within a sample may vary in their requirements for germination because of , for example, differences in maturity between seeds from different plants or between seeds collected from different positions on the same plant (Cavers and Steel 1984; Kane and Cavers 1992; Naylor 1993). [In the experiments to be described here, variation in germination requirements due to these types of factors is not expected to be significant, because only mature capitula have been selected. All capitula used are from the same clone of field grown plants. These capitula have been cleaned and stored in paper envelopes in sealed plastic containers at 5°C.]

In laboratory germination tests, paper is extensively used as a substrate and is particularly suitable for small seeds and for seeds which may require light for germination. The paper should obviously be free from contamination and should allow the roots of germinating seedlings to grow on and not through it. However, paper substrates provide conditions favourable to the development and spread of fungi present on the seeds. Fungi develop less freely on a rougher surface such as sand or glass-fibre. Consequently, a sheet of glass-fibre paper is placed on top of the filter paper and the seeds placed on this. Water loss must be kept to a minimum as germination is dependent on water uptake from the substrate. Controlled, reproducible conditions of light and temperature may be provided by a growth cabinet or incubator.

The germination process can be blocked by chemical and physical factors operating anywhere along the chain of physiological events leading from imbibition of the seed to growth of the embryo. Blockage of germination may be due to the absence of one or more conditions essential for germination. Seeds experiencing such blockages are usually described as experiencing 'dormancy'. This may be enforced (for example, it may result from an absence of moisture in seeds kept under dry storage conditions), innate (resulting from processes occurring within the seed subsequent to the harvest-ripe stage) or induced (resulting from a block imposed as a result of exposure to unfavourable conditions during the imbibed state).

A number of chemicals may break dormancy. For example, potassium nitrate can replace the requirement for, or reinforce the effect of, other dormancy-breaking agents such as light and particular temperature regimes in a large number of species (Roberts 1972). The substrate is moistened with a 0.2% solution of potassium nitrate at the beginning of the test. Similarly, gibberellic acid has been shown to be capable of replacing requirements for light, low temperature and alternating temperatures in a number of species (Roberts 1972). Again the substrate may be treated with a solution of gibberellic acid at concentrations between 0.02% - 0.2%, with the concentration required being determined by the intensity of dormancy.

Seedling evaluation needs to be standardised if germination in laboratory tests are to be reproducible. The definition of germination in a laboratory test is given in International Rules for Seed Testing (1966): it is defined as 'the emergence and development from the seed embryo of those essential structures which, for the kind of seed being tested, indicate the ability to develop into a normal plant under favourable conditions in soil'. The Rules also suggest that seedlings which have developed sufficiently to be correctly assessed are removed at intervals during the test to avoid over-crowding and to restrict the spread of fungi. Any 'doubtful' or abnormal seedlings are left to the end of the test period to ensure that slower growing but otherwise normal seedlings are not incorrectly classified.

Germination tests may take several weeks to perform. More rapid assessments of viability include tests of the metabolic activity of the resting seed. This is the principle of the tetrazolium test, developed by Lakon in 1949. Here, tetrazolium salts are used to indicate activity of enzymes of the dehydrogenase group, which are responsible for reduction processes in living tissue. The chemical is imbibed by the seed as a colourless solution and is reduced by enzymes to formazan which is a red-coloured non-diffusible substance (Moore, in Heydecker 1973). Judgement of the ability of a seed to germinate is based on the degree to which the embryo is stained in the areas essential to growth. Because of this, the embryo needs to be excised for this test. Complete staining is not necessarily essential for an embryo to be classified as being viable, but both the position and extent of necroses are critical as indicators of viability. Since the structure of the embryo varies in different species, different systems of evaluation are employed for different plant groups (Roberts 1972).

The tetrazolium test should not be regarded as a substitute for a laboratory germination test, but it can be used in conjunction with one as it provides additional information. The laboratory germination test identifies the percentage of seeds that are able to germinate immediately, whereas the tetrazolium test identifies the percentage of dead seed. The difference between the two can give an indication of the percentage of dormant seed within the sample. The greatest disadvantages of the tetrazolium test are that it is difficult to conduct and its interpretation requires considerable experience (Copeland 1976). Consequently, it was not used in the present investigation.

3.1.2 Materials and Methods

Achenes from clone W1 were selected for this experiment as this clone exhibited good germination. Capitula from field grown plants of clone W1 were harvested in late summer (August/September). The pappus was removed from each achene. Achenes were subsequently individually stored in paper envelopes in a sealed container at 4°C. For each of 10 months over a period of one year starting in October (months 1-8 inclusive and months 10 and 12), four capitula were removed from storage. Test were not performed in months 9 and 11 as germination rate in preceding months appeared stable. The achenes of each capitulum were weighed individually on a Mettler UMT2 microbalance (see appendix) and grouped into classes according to weight: under 0.2mg, over 0.2 and under 0.3mg, over 0.3 and under 0.4mg, over 0.4and under 0.5mg, over 0.5 and under 0.6mg, over 0.6 and under 0.7mg, over 0.7 and under 0.8mg and over 0.8mg. As most of the <0.2mg achenes were empty, this class was not included in the experiment. This provided 4 replicates for each class size (as far as possible, allowing for differences in weight range for each capitulum) for each experiment. Each weight class was arbitrarily divided into two equal portions: one served as the control, the other received treatment with gibberellic acid/potassium nitrate solution.

Vented 8.5cm petri dishes were prepared by placing 3 sheets of Whatman No.1 filter papers topped by 1 sheet of GFA filter paper in each. These were moistened with either 8ml distilled water (for the control) or 8ml of a solution of potassium nitrate at a concentration of 2g/l together with gibberellic acid (Sigma Chemical Co. (G7645) GA_3 content at least 90% of total gibberellins, $C_{19}H_{22}O_6$, FW 346.4) at a concentration of 0.5g/l. The unsterilised achenes were placed in labelled dishes which were randomly stacked in columns of 6 with a blank dish placed at the top and bottom (sterilisation was not performed, as previous germination experiments had demonstrated that it was not necessary). These stacks were then enclosed in clear polythene bag which were sealed to minimise water loss and placed is an illuminated, cooled incubator at 16h at 16°C (light) and 8h at 8°C (dark). This light/temperature regime was chosen because it approximates conditions in spring and autumn, which are the periods during which most natural germination occurs. Radicle emergence greater than 1mm was the criterion for germination. The dishes were checked daily. Achenes considered to have germinated were removed. Achenes that were diseased and incapable of germination were also removed to prevent the spread of infection. The germination test was terminated when no germination had occurred for 7 consecutive days, or after the test had been running for 30 days, whichever came first. The results were recorded on a daily basis.

3.1.3 Results

After seeking expert advice it was decided to fit a generalised linear model (McCullagh and Nelder 1994) to the data (numbers germinating out of total numbers) with a binomial distribution (as suggested by the form of the data) and logit link function. This transformation uses the expression $(1 - \ln\frac{p}{100-p})$, where p is the probability that the data are linear. Initially, the full model was fitted, including terms for month, achene size (i.e. fresh weight) and treatment, all 2 and 3-way interactions between these terms and also a term for replicates within each month.

The Residual Deviance from this analysis had a value of 519.187 with 376 degrees of freedom; this was highly significant ($p<0.001$). The analysis uses a binomial distribution to describe the data but a chi-squared distribution to describe the Residual Mean Deviance, which explains the goodness of fit of the model. The terms included in the model were tested for significance using approximate F-tests, with the residual mean deviance as denominator and the mean deviance for the term of interest as numerator. (This is analagous to the variance ratio tests in an analysis of variance.)

The 3-way interaction for month.size.treatment was not statistically significant ($p = 0.35$), so the model was re-fitted excluding this term, giving a 2-factor model.

With a generalised linear model, the order in which terms are fitted will influence the deviance ratios; here the order in which terms are fitted was determined by the structure of the experiment. The first term to be fitted was 'month' followed by 'month x replicate', then 'size', 'treatment', 'month x weight', 'month x treatment' and lastly 'treatment x weight'. This allowed the construction of an analysis of deviance table, (Table 10). (This table is equivalent to an Analysis of Variance table). It can be seen from this table that month, weight and their interaction have the most significant effect on germination. (The factor for 'month' has every other factor nested in it and the 'month x replicate' shows a random effect that is of no interest to this investigation.) There is some slight evidence of an overall effect of treatment, with possibly a minor interaction with weight. For these effects, the tables of predicted means (Table 11(i)) and standard errors (Table 11 (ii)), on the logit scale, are given, along with back-transformed predicted means given as percentage germination (Table 11(iii)).

Table 10

Analysis of Deviance Table for achene germination results over a period of one year.

Change	df	Deviance	Mean Deviance	Deviance Ratio	Approx F-prob
month	9	354.55	39.39	28.29	<0.001
month x .rep	30	818.47	27.28	19.59	<0.001
weight	6	2,159.66	359.94	258.45	<0.001
treatment	1	7.97	7.97	5.72	0.02
month x weight	54	188.65	3.49	2.51	<0.001
month x treat	9	18.05	2.01	1.44	0.17
treat x weight	6	19.19	3.2	2.3	0.03
Residual	430	598.87	1.39		
Total	545	4,165.4			

Table 11

(i) Predicted mean germination of achenes grouped according to weight, given on a logit scale.

	Size Category						
wt in mg.	<0.3	up to 0.4	up to 0.5	up to 0.6	up to 0.7	up to 0.8	>0.8
Control	-2.28	0.61	2.25	4.2	4.48	3.78	6.86
Treated	-2.25	0.89	2.52	3.97	4.44	5.02	7.43

Control refers to achenes placed in distilled water substrate, treated refers to achenes placed in gibberellic acid substrate.

(ii) Standard error of predicted mean germination for weight by treatment given on a logit scale.

	Size Category						
wt in mg.	<0.3	up to 0.4	up to 0.5	up to 0.6	up to 0.7	up to 0.8	>0.8
Control	0.26	0.16	0.17	2.09	1.88	0.29	4.11
Treated	0.26	0.16	0.18	2.09	1.88	0.39	4.12

(iii) Back-transformed predicted mean germination for weight by treatment, presented as percentage germination

	Size Category						
wt in mg.	<0.3	up to 0.4	up to 0.5	up to 0.6	up to 0.7	up to 0.8	>0.8
Control	9.27	64.75	90.45	98.52	98.88	97.76	99.89
Treated	9.57	70.83	92.53	98.15	98.83	99.34	99.94

All pair-wise comparisons have been calculated but not presented here as they are too numerous. Whilst all treated means are greater than their equivalent control mean, only the difference for weight category up to 0.8 mg is statistically significant ($p<0.001$). Within the 'control' and the 'treated' achenes (Table 11(iii)), there is a very strong increase in germination with increasing weight up to category 0.6 mg, with germination remaining constant at almost 100% in this weight class and in all higher classes.

Tables 12 (i-iii) present the 2-way tables for month by weight. In cells where all achenes germinated, the logit tends to infinity; these situations are indicated with values of >+10, and no standard errors are given. However all pairwise comparisons for the predicted mean germination in these tables have been calculated.

Table 12

(i) Predicted mean germination of achenes grouped according to weight x month given on a logit scale.

Month 1 is October.

	Weight Category						
wt in mg	<0.3	up to 0.4	up to 0.5	up to 0.6	up to 0.7	up to 0.8	>0.8
Month 1	-1.35	1.19	1.87	4.25	>10	4.61	>10
2	-3.31	0.62	2.28	2.42	1.92	1.41	1.23
3	-0.79	1.7	4.11	>10	5.42	5.96	5.02
4	-2.76	1.34	3.26	4.88	4.27	6.05	>10
5	-1.1	0.59	2.59	3.21	4.06	5.96	4.94
6	-2.71	0.59	2.41	3.35	3.22	4.09	>10
7	-2.96	-0.08	1.34	1.5	2.64	2.43	3.04
8	-2.87	0.1	2.06	3.62	5.15	4.28	5.06
10	-3.43	0.53	1.99	1.75	2.37	2.98	3.5
12	-1.72	0.77	1.55	2.72	3.42	5.34	>10

Table 12

(ii) Standard errors for predicted mean germination of achenes grouped according to weight x month on a logit scale.

		Size Category					
wt in mg.	<0.3	up to 0.4	up to 0.5	up to 0.6	up to 0.7	up to 0.8	>0.8
Month 1	0.39	0.3	0.3	0.7	-	0.87	-
2	0.66	0.37	0.39	0.48	0.44	0.34	0.57
3	0.41	0.38	0.73	-	1.21	1.22	0.75
4	0.66	0.51	0.54	0.65	0.56	0.96	-
5	0.38	0.33	0.4	0.49	0.58	1.21	0.87
6	0.55	0.36	0.39	0.45	0.35	0.54	-
7	0.95	0.39	0.34	0.29	0.34	0.37	0.42
8	0.89	0.34	0.38	0.61	1.19	0.72	0.72
10	0.9	0.41	0.34	0.28	0.3	0.37	0.5
12	0.53	0.32	0.33	0.39	0.45	1.21	-

(iii) Predicted mean germination of achenes grouped according to weight x month back-transformed to percentage germination.

		Size Category					
wt in mg.	<0.3	up to 0.4	up to 0.5	up to 0.6	up to 0.7	up to 0.8	>0.8
Month 1	20.65	76.64	86.67	98.59	100	99.01	100
2	3.53	65	90.68	91.8	87.16	80.36	77.35
3	31.32	84.58	98.38	100	99.56	99.74	99.34
4	5.95	79.25	96.31	99.25	98.62	99.76	100
5	24.97	64.36	93.05	96.13	98.3	99.74	99.29
6	6.22	64.24	91.77	96.61	96.15	98.35	100
7	4.92	47.95	79.18	81.7	93.35	91.94	95.43
8	5.38	52.55	88.69	97.4	99.42	98.63	99.37
10	3.13	63.04	88	85.25	91.43	95.16	97.05
12	15.2	68.24	82.52	93.81	96.82	99.52	100

Again , the general increasing trend in germination rate with increasing size up to about 0.5 to 0.6 mg is clear; above this size, germination is 95% or greater. The lowest rates of germination are for the smallest size category; these vary considerably between the different months (approximately 3% germinations in months 2 and 10 to 31% germination in month 3). There is also a lot of month to month variability for achenes 0.3-0.4 mg (from 48% to 85%) germination. Month 2 appears to have lower germination rates for the larger achenes (0.6 - >0.8mg) than the other months.

3.1.4 Discussion

The results presented in the previous section indicate that time, achene size and their interaction significantly influence achene viability. There also appears to be a minor interaction effect with size that is associated with an increase in germination rates. However, the differences are small as shown by Tables 11: (i)-(iii), for the weight by treatment combinations. The achenes used in this experiment were stored in controlled conditions (as per 3.1.2) for the duration (1 year) of the experiment. It is perhaps likely that the loss of viability over time is more pronounced under natural, and therefore more variable, environmental conditions. Certainly, it has been reported that *Taraxacum* does not produce a persistent seed bank (Grime, Hodgson and Hunt, 1988).

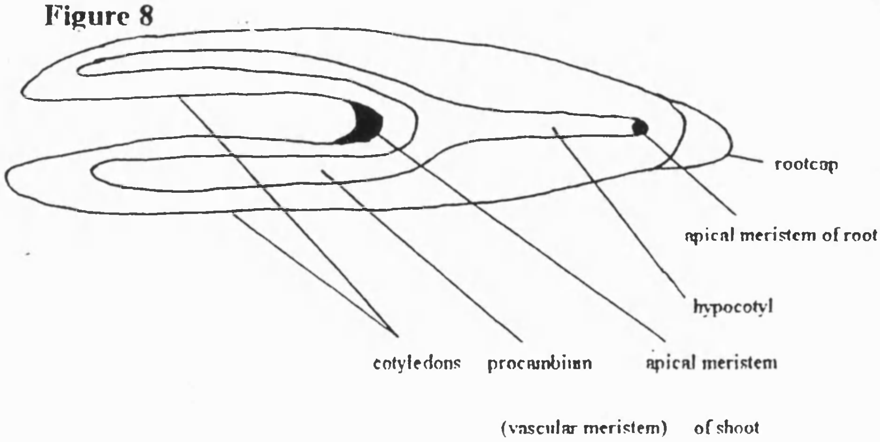
The results also indicate that the size of an achene will influence its probability of germination, with larger achenes being more likely to germinate than smaller ones. This effect persisted for the duration of the experiment. Table 12 (iii) shows that achenes over 0.6mg have a germination rate of between 80-100% over the period of 1 year. Below 0.5mg, the germination rate is very erratic. There may be several explanations for this erratic germination. For example, smaller achenes sometimes contain immature embryos that are incapable of germination. Or it may be because the smaller embryos contained within smaller achenes are more prone to death through dehydration than larger embryos. Alternatively, smaller embryos may be more prone than larger embryos to infection by bacteria or fungi.

3.2 Germination of Excised Embryos *in vitro*.

3.2.1 Introduction

The main purpose of this investigation was to determine how embryos behave during and after germination and to ascertain if there are any differences in growth between large and small embryos and ultimately between heavy and light achenes. The embryo of a seed plant has a relatively simple structure compared with the adult plant. The embryo has a limited number of parts--- frequently only an axis bearing one or more cotyledons- and its cells are mostly at a low level of differentiation. However, because of the presence of root and shoot meristems at opposite ends of the axis, it has a potentiality for further growth. Figure 8 shows the organisation of a typical mature embryo of *Lettuca sativa* (lettuce) in longitudinal view (after Esau 1965; not to scale).

Figure 8



In exploratory experiments (Sheppard 1993), the embryo of *Taraxacum* was found to be torpedo shaped. It consisted of opaque white cells which were densely packed, and it lacked any distinguishing marks. The development of an angiosperm embryo includes several stages (Steeves and Sussex 1972). Early in development, divisions of the surface cells become restricted to the anticlinal plane (i.e.perpendicular to the surface), resulting in the appearance of a superficial layer called the protoderm. After this, a central column of narrow, elongated procambial cells surrounded by a cylinder of vacuolated cells develops. At this stage, the principal tissue systems of the plant have been initiated. The shoot apical meristem then appears, followed by the development of two cotyledons as a result of localised concentrations of growth on either side of the shoot meristem (but not in it). This stage is known as the 'heart-shaped' stage. Procambium noncontinuous with that of the central core of the embryo axis extends into the cotyledons. As the cotyledons enlarge, the axis of the embryo elongates and, at the end of the axis opposite the shoot apical meristem, a root cap is initiated beneath which the apical meristem of the primary root can be detected. The mature embryo is bi-polar with shoot and root apical meristems located at opposite extremities of the axis. The mature embryo possesses the fundamental organization of the adult plant, but the root and shoot systems are represented only by their respective meristems. These meristems have unlimited growth potential. Germination comprises the physiological and physical changes that the seed undergoes immediately prior to, and including, the first visible indications of growth (Esau 1965). Both internal and external conditions need to be favourable for germination. The dehydrated seed will need water for germination, and factors causing dormancy may need to be overcome. Also temperature and light requirements need to be met (see sections 3.1.1 and 3.1.1(a) for a more detailed account of germination requirements). Following imbibition by water, the respiration rate of the embryo in a germinating seed increases markedly, as food reserves are broken down and protein synthesis commences. The radical is normally the first organ to emerge through the testa, followed by the plumule.

The investigation reported below involved measuring the lengths, over a period of time, of embryos excised from achenes of known weight. Its purpose was to measure the rate of embryo elongation, which provides a quantitative assessment of embryo growth.

3.2.2 Materials and Methods

Batches of 10 achenes, selected from a capitulum from clone W1, were weighed on a Mettler UMT2 microbalance. The achenes were placed in labelled cells of a petri dish and left to soak in distilled water for 24 hours. After this period, the embryos were excised, as previously described in chapter 2, and placed on a square of GFA paper that had been moistened with distilled water and placed on a labelled microscope slide. The length of the embryo was recorded using a calibrated microscope at x40 magnification. This slide was then placed across another slide at right angles and put into a petri dish containing 3 sheets of Whatman No.1 filter paper moistened with 5mls. of distilled water. The petri dishes were placed in an illuminated incubator kept at 16h at 16^{0}C (light)/8h at 8^{0}C (dark). This light/temperature regime was the same as that used for the germination experiment. Each day, for 5 consecutive days, the embryos were removed from the incubator and measured.

3.2.3 Results

It was not possible to obtain a satisfactory estimate of the growth of the embryos, as cotyledons were often apart and curved by day 2, and as the radical had usually become curled (with root hairs clearly visible) and the cotyledons had turned green by day 3. It was not possible to refine the methodology in order to generate reliable data in the time available.

Plate 1

The variation in size of achenes from the same capitulum

Plate 2

Achene with half of the coat cut away to show position of the embryo within.

Plate 3

Achenes with their embryos alongside to show variation in embryo size.

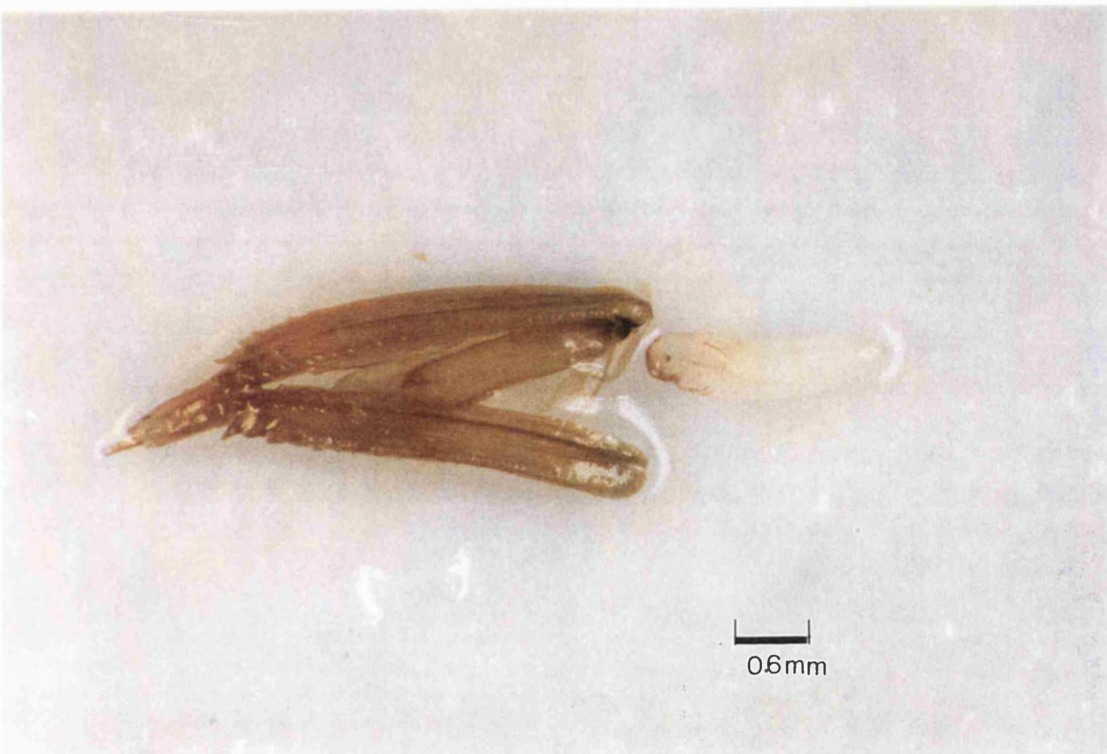
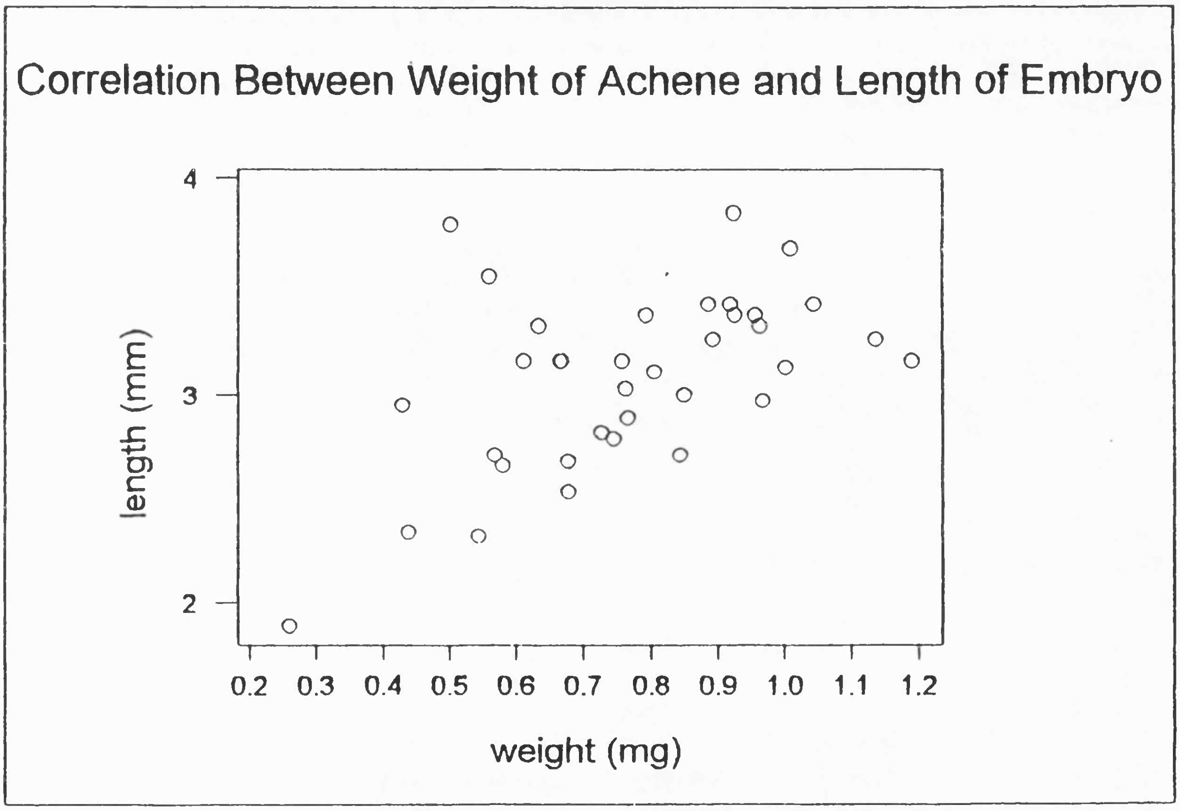


Figure 9:


Correlation Between Weight of Achene and Length of Embryo
length (mm)
4
3
2
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
weight (mg)

However, it is possible to determine the correlation between the weight of an achene and the initial length of its embryo. The scatter plot (figure 9) shows that larger and heavier achenes tend to contain longer embryos (although there is considerable variation). Plates 1-3 show examples of this variation.

A regression of embryo length versus fresh achene weight gave the equation:

Embryo length (in mm) = 2.25 + 1.07 (fresh achene weight in mg)

$r^2 = 0.288$ Anova: $F = 14.18$ $p = 0.001$

This regression is significant. The coefficient of determination (r^2) shows that 28.8% of the variation in the length of embryos is explained by variation in achene fresh weight. Thus, overall, it can be concluded that larger and heavier achenes contain longer, and therefore presumably heavier embryos.

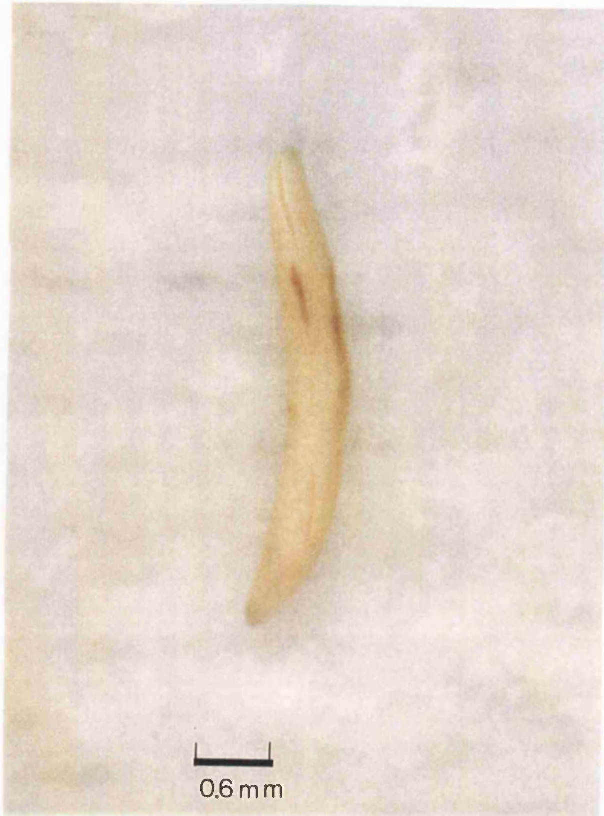
3.2.4 Discussion

From the experiments reported in this chapter, it can be concluded that heavier achenes tend to contain heavier embryos which are also generally longer than embryos from lighter achenes. The variation observed in the size of embryos is indicated in plates 1-3. Generally, heavier achenes have a higher rate of germination than lighter achenes. This may be because the embryos of heavier achenes contain more cells that can be activated on imbibation. This may result in vigorous seedlings. In contrast to the germination of initial material quoted in chapter 2 (section 2.1.2), time to germination, taken as radicle emergence greater than 1mm does not vary significantly with size (weight) of achene. However, the criteria for germination adopted in this chapter and chapter 2 were different (appearance of cotyledons above compost level in chapter two against radicle emergence in a moist substrate in a petri dish in this chapter). In addition, the achenes used in the germination versus time experiment had been stored in controlled conditions, thus probably optimising germination potential.

Stages in the growth of embryos are shown in plates 4-8. The following general observations were made concerning embryo growth. On day 0 (at excision) the embryo was either intact or showed some evidence of division between the cotyledons. By day 1 (after 1 day in the incubator), the cotyledons were well apart and the radicle had elongated and in most cases had started to curl. By day 2 the cotyledons had started to turn green and root hairs had formed on the radicle. Thus given the right conditions for growth the embryo reaches the stage of having green cotyledons (which are presumably photosynthetically active) within 3 days of imbibation. This is a shorter time to the green cotyledon stage than that recorded for achenes planted into compost or germinated on petri dishes. Presumably, the acceleration of seedling development in excised embryos is a result of the radicle not having to break through the achene wall.

Plate 4

Newly excised embryo.



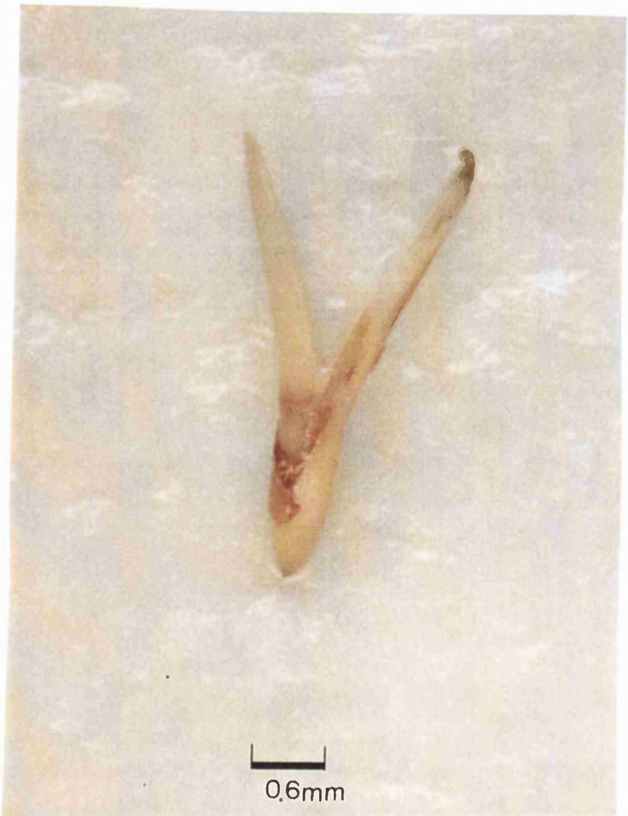
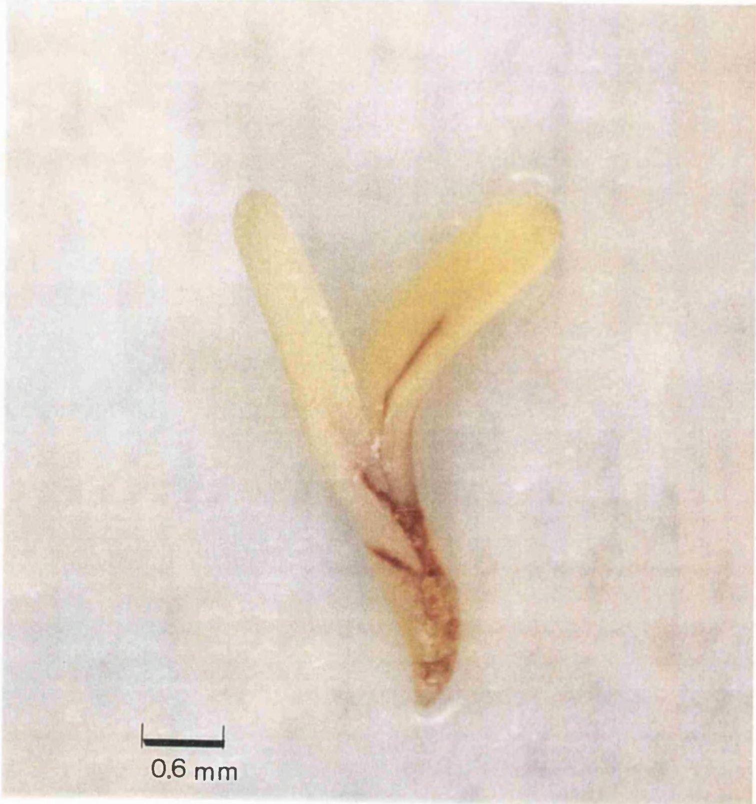


Plate 5

After 1 day: cotyledons apart.

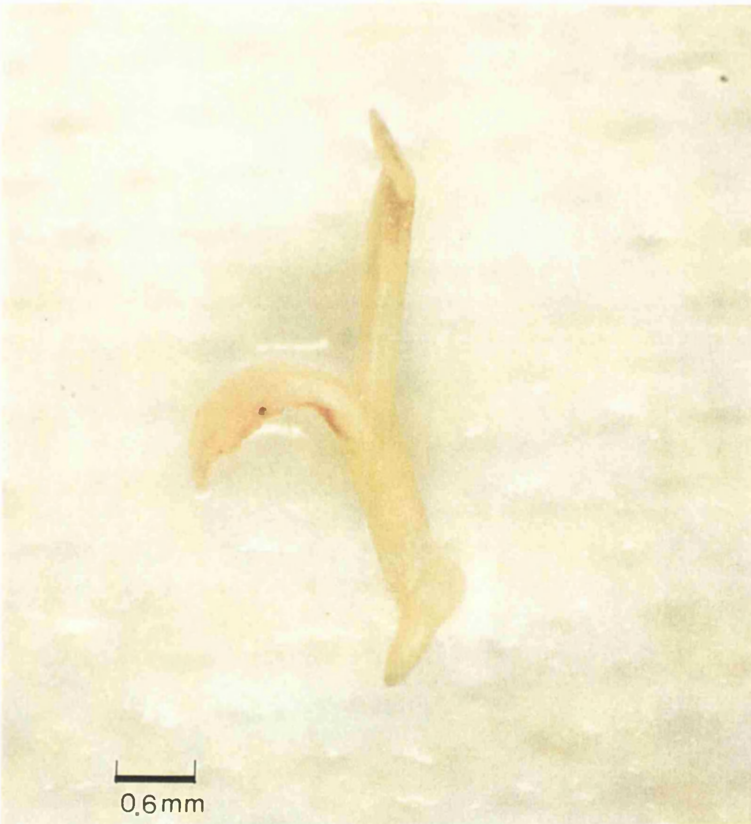
Brown colour is remaining protoderm.

Plate 6



Elongation of radicle occurring.

Plate 7



After 2 days: root hairs forming and curling of radicle beginning.

Plate 8

After 3 days: cotyledons green and well apart, proliferation of root hairs.

Chapter 4

This chapter and also the following chapter are concerned with plant growth. This chapter deals with experiments conducted in the greenhouse.

Laboratory experimentation enables the characteristics of plants to be measured under a variety of controlled conditions. Such investigations may be reproduced or extended wherever there are adequate facilities, and hence data collected on different species or genotypes and in various laboratories may be compared directly. This approach has been used extensively in the study of plant growth rates.

4.1 (a) Data Interpretation

The growth of whole plants is normally assessed by methods developed in the 1920's (Whitehead and Myerscough 1962; Richards 1969). These involve a comparison of growth rates over a time interval, the measure of interest being the weight and area of plants harvested at the start and end of the interval. These measurements indicate how the plant grew during the period in question, but the data are seldom combined to produce an overall picture of the growth process.

The ratio of mean relative growth rate (R) to mean relative rate of leaf area increase (R_L) provides a measure of the growth of the plant. This ratio, is designated α, can be used in the accurate determination of net assimilation rate (E). It is usual to express R,R_L and E in units of weight and leaf / area / week.

In order to obtain accurate estimates of growth parameters, it is necessary to have sample sizes of 10-20 plants per harvest, although relatively few harvests need to be made. However, for reasons of efficiency the use of frequent, but small harvests has been recommended (Hughes and Freeman 1967; Nicholls and Calder 1973; Hurd 1977).

Hurd (1977) used frequent small harvests at the expense of replication at each harvest. He obtained a continuous assessment of gain in dry weight and in leaf area with time by fitting the values obtained at each harvest to an appropriate equation. In brief, all the growth curves he obtained for both leaf expansion and dry weight gain were similar and could be described by the quadratic polynomial relation in the form of

$$y = a + bt + ct^2$$

where a, b and c are constants, t is the measured parameter and y is the dependent variable.

This is the so called "functional approach" (Causton and Venus 1981; Hunt 1984). In the functional approach a polynomial of the general form $Y=b_0+b_1X+b_2X^2+.......b_nX^n$ is fitted through the growth data. Hughes and Freeman (1967) used frequent small harvests and regressed the logarithms of both total dry weight and leaf area against time. Differentiation of the regression equations gives the progress curves of relative growth rates, unit leaf rate and leaf area ratio. Nicholls and Calder (1973) have also demonstrated ways in which appropriate polynomial regression equations can be objectively applied to the total weight/time relationship. They discuss the implication of fitting an inappropriate regression equation and comment that "over-fitting" is a real trap as this procedure indicates relationships between RGR (relative growth rate) and time, or NAR (net assimilation rate) and time that the raw data do not adequately support. For example, the acceptance of a lower order polynomial may result in a simplification of the relationships of the two growth parameters that again is not adequately supported by the data. Also, the acceptance of a lower order polynomial may result in a simplification of the two growth parameters with time to a degree which may appear biologically ridiculous. Nicholls and Calder (1973) found very little evidence to support the use of cubic relationships. The question of which degree of polynomial should be fitted to the plant data for purposes of growth analysis has been considered in relation to the variability of the populations sampled. Thus Elias and Causton (1976) have found that the variability of harvest samples can have a profound effect on the determination of significance when relationships are derived from individual observations. Thus significance tests performed on data of low variability resulted in over fitting (i.e.

unrealistically high degrees of polynomials (quartic or quintic) were indicated as being most explanatory). The authors also showed that data of high variability were adequately fitted by lower order polynomials. They suggested that growth data should be fitted using harvest mean values, since this method provides a test of adequacy of fit that is independent of the population variability.

The polynomial function offers a mathematically convenient way of describing plant growth; but it is not based on any biological model. A more complicated model to describe plant growth, in particular leaf growth, involves the use of the Richards function (Causton, Elias and Hadley 1978), which is defined as the differential equation:

$$\frac{dW}{dT} = \frac{kW}{nA^n}(A^n - W^n),$$

where W is the value of a growth attribute at time t,and A and K are positive constants. constant n can lie in the range -1 $\leq$ n $\leq$ ∞, but n $\neq 0$. On integration the function becomes W + $(1 \pm e^{(b-kt)})^{-\frac{1}{n}}$, where b is the constant of integration. Most growth attributes are log-normally distributed, and the Richards function is more commonly written and used in its logarithmic form:

$$\log_e W = \log_e A - (1/n).\log_e(1 \pm e^{(b-kt)})$$

This form was used in experiments to analyse the effects of temperature on leaf growth (Causton, Elias and Hadley 1978) because it was thought that exponential growth (which implies a constant growth rate) did not adequately describe growth of higher plants, and thus an alternative and more accurate model had to be used. The use of the Richards function in plant growth analysis (instead of polynomial exponentials) was strongly recommended by Venus and Causton (1979 a). However, in another paper Venus and Causton (1979 b) questioned the justification for using fitted functions in estimations of relative growth rates and net assimilation rates. They introduced a method of analysis which avoided their use.

4.1 (b) Current Methods

Poorter and Lewis (1986) argue that a suitable test for differences in relative growth rates comprises an analysis of variance with log-transformed plant weight as the dependent variable. A significant group x time interaction indicates differences in relative growth rates between groups. The authors point out that there are several advantages associated with this approach. These include:- no pairing is required (normally, when harvests are destructive, individual replicates of one harvest have to be paired with those of the next); more than two groups may be evaluated in one analysis; no decision about the appropriate polynomials to fit the data need be made; and, orthogonal polynomials are used to partition the interaction effect. This approach, which provides insight into the nature of differences in the relative growth rates, generates a set of polynomials of increasing order that are constructed as a set of independent (orthogonal) contrasts. This approach is often referred to as trend analysis (Sokal and Rohlfe 1981; von Ende 1993). It enables questions to be asked about whether there is a significant linear (1st order), quadratic (2nd order) or cubic (3rd order) trend in the data. If k is the number of levels of within-subject factor then (k - 1) polynomials can be constructed. One would usually be interested in the lower order (linear, quadratic) trends only. In the analysis of the within-subject factor(s), MANOVA (multivariate analysis) considers simultaneously all orders of polynomials that can be obtained from the data. In examining orthogonal polynomials, it is usual to proceed from higher to lower order in testing for significance, and stopping at the order of polynomial at which significance is found.

In all the previous work mentioned, relative growth rate is determined by dry weight sampling and destructive harvesting. (RGR is calculated by dividing the difference in log-transformed plant weight at two harvests by the time difference between those harvests). A major problem with this classical approach is that it is impossible to obtain a direct estimate of the variance of relative growth rate, because this rate is calculated from two samples of plants, with a different sample taken for each harvest. These are not true replicates. If fresh weight is used, however, it is possible to use the same individual for successive determinations of relative growth rate, thereby obtaining a direct estimate of the variance of relative growth rate. Comparing direct estimates of variance using fresh weight with indirect estimates using dry weight identifies the correction factor that needs to be applied to the indirect estimate using dry weight. Using this term will improve the efficacy of experiments in which classical (i.e. dry weight based) methods of plant growth analysis are used (Causton 1991).

Growth experiments are examples of repeated measures analysis where there is an explicit interest in the response (plant height, weight) over time. Data collected in experiments where the response is monitored over a time period is frequently analysed by an Analysis of Variance. Parametric methods of analysis may either be by a univariate (randomised block, split-plot) Anova, using 'time' as the split-plot/repeated (within-subject factor) or by a multivariate approach.

4.2 Growth Experiments Under Controlled Conditions

(a) Non-destructive sampling of the post germination stage.

Introduction

Many of the problems outlined above that are associated with plant growth analysis (in particular those associated with pairing) can be eliminated if non-destructive sampling is employed. Hommels *et al.* (1991) used non-destructive sampling to measure growth in *Taraxacum*. Seedlings were planted out in tanks containing a nutrient solution which was renewed weekly. Plants were selected for uniform size and moved to avoid mutual shading when necessary. More than one growth cabinet had to be used to accommodate the experiment and the authors acknowledge that this could cause fluctuations in environmental conditions. (A detailed description of problems encountered with experiments in the controlled conditions of growth cabinets is given by Potvin 1993.) Causton (1991) used a non-destructive approach in greenhouse experiments to assess the variability of growth rate within a sample of plants. He calculated the factor 'r', the correlation between continuously monitored fresh weight data and the data obtained in classical growth analysis (i.e. destructive harvesting). Sheppard (1993) obtained a value of r = 0.964 for *Taraxacum*.

The advantage of measuring growth in a greenhouse (compared with using growth cabinets) is that a greenhouse provides sufficient space to conduct large experiments without the need for duplication of environmental conditions. A suitable technique for non-destructive sampling in a greenhouse is the Nutrient Film Technique (NFT). This involves the use of a simple hydroponic system of the type often employed in horticulture (Cooper 1976). Plants grow in polythene channels through which a balanced nutrient solution is continuously circulated. In a pilot experiment conducted (during the course of this research) to assess the suitability for using this method to grow *Taraxacum* plants to maturity, plants initiated flowering after 130 days. A limiting factor was found to be the temperature of the nutrient solution and hence the temperature of the roots. Temperatures of over 30°C for a day or more resulted in signs of leaf death (leaves became 'crisp' and fragile and disintegrated on touch).

Materials and Methods

An NFT system with six channels was set up in a heated greenhouse maintained on a 16h/16°C day, 8h/8°C night cycle. The experiment was conducted in the winter in order to minimise the chance that the nutrient solution would reach the critical temperature of 30°C.

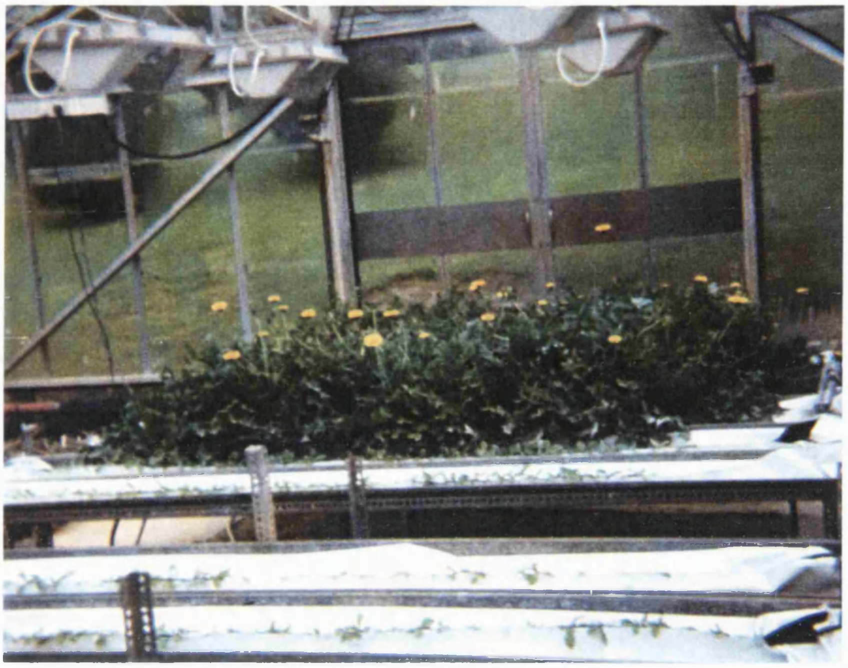
Table 13 Composition of starting solution.

SALT	STOCK SOLUTION ($g\ l^{-1}$)	DILUTION ($ml\ l^{-1}$)	CONCENTRATION (ppm)
Calcium nitrate	787	1.25	117(N) 168(Ca)
Potassium nitrate	169	3.9	254 (K) 91 (N)
Magnesium sulphate	329	1.5	49 (Mg)
Potassium phosphate	91	3	62 (P) 78 (K)
Chelated iron	12.3	3	5.6 (Fe)
Manganese sulphate	3	3	2.2 (Mn)
Boric acid	1.23	1.5	0.32 (B)
Copper sulphate	0.17	1.5	0.065(Cu)
Ammonium molybdate	0.01	1.5	0.007 (Mo)
Phosphoric acid		0.04	23 (P)

Table 14 Composition of Topping-up solution.

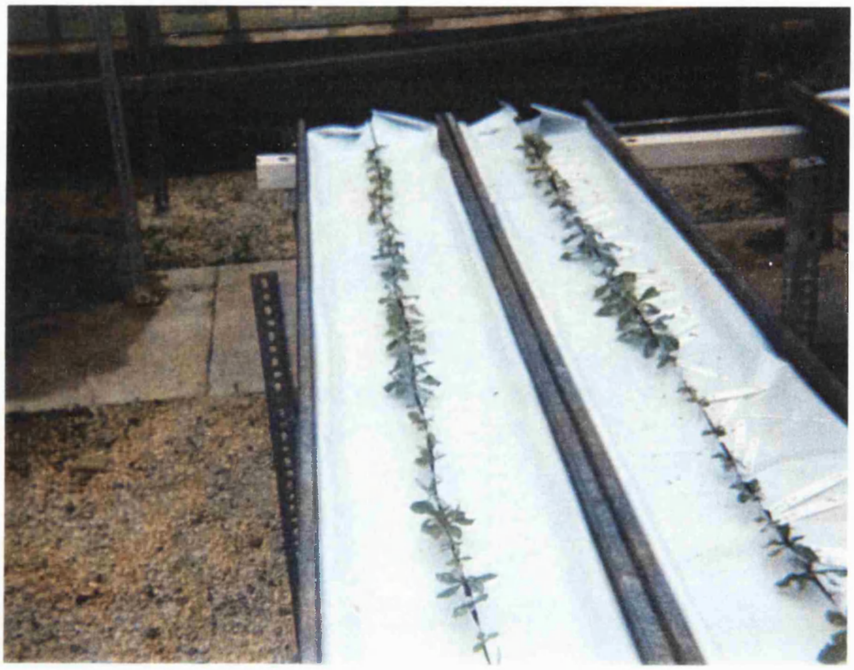
SALT	STOCK SOLUTION (gl^{-1})	DILUTION ($ml\ l^{-1}$)	CONCENTRATION (ppm)
Calcium nitrate	787	0.5	47 (N) 67(Ca)
Magnesium sulphate	329	1	32 (Mg)
Potassium nitrate	169	2.13	147 (K) 51 (N)
Chelated iron	24.5	0.4	1.5 (Fe)
Manganese sulphate	7.42	0.3	0.55 (Mn)
Copper sulphate	1.7	0.15	0.065 (Cu)
Ammonium molybdate	0.6	0.15	0.007 (Mo)
Boric acid	6.17	0.3	0.32 (B)

Plate 9



Growth experiments using the NFT system. Plants in the foreground are for the root/shoot allocation experiment. Plants in flower are part of the environmental sensitivity experiment.

Plate 10



Close up of the NFT channels, showing plants for non-destructive harvesting experiments "clipped" into the polythene lined channels.

The NFT system involved linking six polythene lined channels, set on a slight gradient, to a 70 litre tank containing a submerged pump. The nutrient solution was pumped to the top end of each channel. From there the solution flowed downhill to collection pipes and was passed back into the tank to be re-circulated. The tank and all pipes were covered in black polythene to reduce algal growth, whilst channels were lined with two layers, black polythene inside white polythene for extra durability.

Stock solutions (both starting and top-up) of component salts were made up as shown in Tables 13 and 14 (from Cooper 1976). 70 litres of starting solution were made by adding the relevant amount of stock salt solution to the water. For example: Calcium nitrate stock solution contained 787g of the salt per litre. The starting solution needed a dilution of 1.25ml per litre, the tank holds 70 litres, so, 70 x 1.25 or 87.5 ml of calcium nitrate solution was added to the tank to give the correct concentration. The composition of the topping up solution is different to that of the starting solution as the constituent minerals are depleted at different rates. The balance of salts in the solution was monitored using a portable Bibby conductivity meter. When the conductivity of the solution fell below 2mS (milli-Siemens), the appropriate volumes of top-up salts were added. The pH of the solution was maintained between 6 and 7 for by the addition of a calculated volume of phosphoric acid.

Achenes from clones W3 and M2 were weighed individually using a Mettler UMT2 microbalance and then sorted into 3 weight classes: <0.5mg; 0.6-0.7mg and >0.7mg. Ten achenes from each weight class for each clone were placed individually on Vermiculite contained in small, labelled plastic tubs with a mesh base. (The tubs were 4cm deep, with a diameter of 3cm, the bases having been removed and replaced with a fine plastic mesh.)

The tubs were placed on a heated greenhouse bench under a mist unit. On germination, the tubs were transferred to the NFT system, being placed directly in the nutrient solution in the channels. When the roots had emerged through the mesh, the seedlings were carefully removed from the tubs and suspended directly in the channels, with their roots submerged in the nutrient solution. This was done by clipping the edges of the polythene linings together either side of the seedling with large paper clips. At weekly intervals, the plants were removed from the channels; their roots were suspended in flasks containing distilled water until the plants were weighed. The roots were carefully blotted dry with filter paper and the plants were weighed. Small plants were weighed using a microbalance. Larger plants were weighed using a top-pan balance.

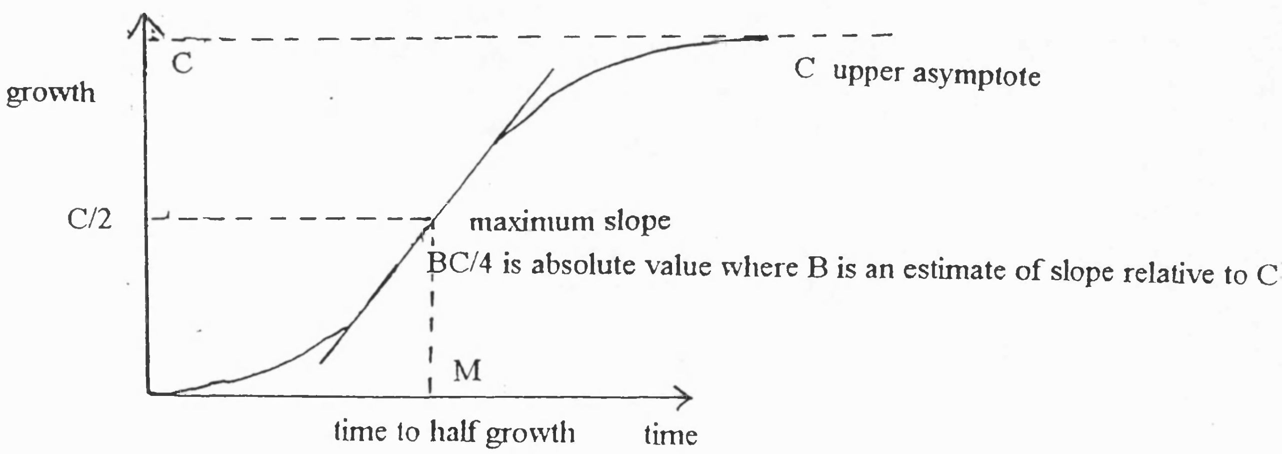
This technique gives continuously monitored fresh weight data. The experiment was continued until day 77. (It was ended here because the temperature rose sharply in spite of ventilation and there was a severe infestation of powdery mildew (*Erysiphe* sp.)).

Results

Following advice from a statistician, the data were analysed by fitting a logistic curve to the measurements for each plant separately. A logistic curve is summarised by the expression $\frac{C}{1+\exp(-B(T-M))}$, where T = Time in days, C = Upper asymptote , M = Time to 1/2 growth, and B = a measure of relative slope at M. Time to half growth is the time taken to reach half the final recorded growth.

Figure 10

The logistic curve (diagrammatic) with the parameters to be measured marked.



The fitted parameters B, C and M were obtained, and the absolute maximum slope, which is given by the expression BC/4, was calculated. Tables 9 (i) and (ii), overleaf summarise these parameters. B, C, M and the maximum slope (BC/4) were analysed with respect to clone and size category and their interaction. There were unbalanced sets so a regression was used. The resulting analysis of variance for each regression, taking each parameter in turn, showed that for B (the relative slope), there was no significant difference between the size classes, clones or their interaction. This also held true for an analysis where the factors were the linear effect of size, clone and their interaction and also for a comparison of clone with size and their interaction.

Table 15

(i): Clone W3: fitted parameters for each plant.

B	M	C	Max slope	Size
0.21	51.88	2.3	0.12	1
0.18	51.11	4.21	0.19	1
0.09	49.01	0.25	0.01	1
0.14	51.42	3.09	0.11	1
0.15	50.81	3.16	0.12	1
0.23	51.81	0.58	0.33	1
0.1	54.67	0.75	0.02	1
0.13	51.88	6.96	0.23	2
0.12	53.11	9.28	0.28	2
0.19	47.91	0.73	0.04	2
0.11	57.31	2.47	0.07	2
0.12	54.02	11.45	0.36	2
0.13	52.89	2.51	0.08	2
0.12	49.44	10.54	0.33	3
0.13	52.06	13.31	0.45	3
0.15	49.52	5.24	0.2	3
0.15	53.14	9.79	0.36	3
0.15	53.01	0.54	0.02	3
0.21	48.97	1.05	0.05	3

Size1 refers to achenes <0.5mg fresh weight, size 2 to achenes 0.6 - 0.7mg fresh weight and size 3 to achenes >0.7mg fresh weight.

Table 15

(ii) Clone M2: fitted parameters for each plant.

B	M	C	Max slope	Size
0.16	52.77	10.12	0.41	1
0.18	53.16	1.82	0.08	1
0.16	53.21	11.68	0.4	1
0.17	50.99	6.06	0.26	1
0.17	50.55	7.08	0.29	1
0.15	50.58	3.87	0.14	1
0.15	51.21	7.57	0.29	1
0.13	51.14	5.88	0.18	1
0.2	51.34	4.35	0.22	2
0.13	53.59	9.23	0.3	2
0.06	60.25	0.36	0.01	2
0.15	52.82	5.84	0.23	2
0.16	51.56	10.27	0.41	2
0.12	54.65	9.98	0.31	2
0.18	52.85	6.87	0.3	2
0.15	52.52	5.8	0.21	2
0.15	55.36	3.62	0.13	2
0.14	53.06	11.71	0.42	3
0.15	51.16	10.32	0.39	3
0.13	53.74	6.09	0.2	3
0.15	49.01	14.26	0.54	3
0.13	50.83	2.09	0.07	3
0.18	52.53	4.12	0.18	3
0.14	5.1	11.97	0.43	3

Table 16

This gives the predictions from the regression for mean and standard error of the mean for response variate B, which is the estimate of the slope relative to the upper asymptote.

(i)

clone	mean	sem
W3	0.14765	0.00769
M2	0.14969	0.00684

(ii)

size	mean	sem
<0.5mg	0.15733	0.00865
0.6-0.7mg	0.13997	0.00867
>0.7mg	0.14911	0.00928

(iii)

size	1		2		3	
clone	mean	sem	mean	sem	mean	sem
W3	0.1572	0.0126	0.1345	0.0137	0.1518	0.0137
M2	0.1574	0.0118	0.1443	0.0111	0.1469	0.0126

The Analysis of Variance of the regression for the variate M, the time to half growth, showed a significant size effect ($p<0.021$) is summarised in Table 17.

. **Table 17**

Predictions from the regression for mean and standard error of mean for the response variate M, the time to half growth.

(i)

clone	mean	sem
W3	51.838	0.487
M2	52.438	0.433

(ii)

size	mean	sem
<0.5mg	51.626	0.548
0.6-0.7mg	53.429	0.549
>0.7mg	51.355	0.588

(iii)

size	<0.5mg		0.6-0.7mg		>0.7mg	
clone						
W3	51.529	0.801	52.854	0.865	51.023	0.865
M2	51.702	0.749	53.884	0.707	51.617	0.801

The Analysis of Variance from the regression for the variate C, the upper asymptote, or final growth, revealed an overall clone difference ($p<0.039$) and an indication of a significant linear trend for size (fresh weight) ($p<0.029$). The analysis is summarised in Table 18.

Table 18

Predictions from the regression for mean and standard error of mean for the response variate C, the upper asymptote.

(i)

clone	mean	sem
W3	4.696	0.868
M2	7.156	0.771

(ii)

size	mean	sem
<0.5mg	4.678	0.975
0.6-0.7mg	5.952	0.978
>0.7mg	7.809	1.047

(iii)

size	<0.5mg		0.6-0.7mg		>0.7mg	
clone						
W3	2.05	1.43	5.57	1.54	6.75	1.54
M2	6.76	1.33	6.26	1.26	8.65	1.43

The predicted means in Table 18 (i) show clone M2 >clone W3. That is, final growth is greater for M2 than for W3. Table 18 (ii) shows a significant increase with increasing size category from 1 to 3. That is, final growth increases with increasing fresh achene weight.

The final parameter to be analysed was the maximum growth rate. The Analysis of Variance indicated an overall clone effect ($p<0.01$) with slight evidence of a linear trend for size ($p<0.059$). Table 19 (i)-(iii) present the predicted mean and sem for each analysis.

Table 19

Predictions from the regression for mean and standard error of mean for the maximum growth rate.

(i)

clone	mean	sem
W3	0.1615	0.0307
M2	0.2705	0.0273

(ii)

size	mean	sem
<0.5mg	0.1857	0.0345
0.6-0.7mg	0.208	0.0346
>0.7mg	0.2812	0.037

(iii)

size	<0.5mg		0.6-0.7mg		>0.7mg	
clone						
W3	0.0857	0.0504	0.1742	0.0545	0.2343	0.0545
M2	0.2649	0.0475	0.2347	0.0445	0.3183	0.0504

The predicted means and sem presented in Tables 16-19 have been used in the following t-tests. The variate B (the relative slope) shows no indication of any clone or size effects throughout the analysis. The variate M (the time to half growth) shows a possible size effect in the Analysis of Variance. However, the approximate t-tests (using the predicted means presented in the Tables 16-19 above) shows that clone difference is not significant. Nevertherless, there is a size effect, with size 2 (achene fresh weight 0.6-0.7mg) having a greater value than either of the other size classes ($p<0.05$ with 2df).

Both clone and size differences are indicated for C (final growth) by the Analysis of Variance. The t-tests showed that clones differences (M2>W3) are significant ($p<0.05$ with 1df). Size differences were also significant ($p<0.05$ with 2df) with 0.7mg > 0.6-0.7mg >

0.5mg. Finally, a significant clone effect is detected by the Analysis of Variance for maximum growth rate. The t-tests on predicted means shows that M2 >W3 ($p<0.05$ with1 df).

Discussion

M2 outperformed W3 in both final growth and maximum growth rate. For both clones, achene size differences are shown to have an effect on the time to half-growth and on final growth. Achenes in the category 0.6-0.7mg had a greater time to half growth than both of the other size classes (i.e 0.5mg and >0.7mg). This indicates a slower growth rate at the start of growth for 'mid-range' achene weight. There is no obvious explanation for this. For both clones, final growth is influenced by achene size, with larger achenes producing larger plants within the time span of this experiment. Taking this information in conjunction with the results of the experiments described in chapter 3, it appears that heavier achenes have a higher rate of germination and produce bigger plants after 77 days of growth.

(b) Destructive sampling to determine allocation to root and shoot during the first 11 weeks of growth.

Introduction

An experiment designed to assess changes in root/shoot allocation during the early stages of growth was conducted at the same time as the experiment described above. Previous investigations have yielded conflicting evidence about whether achenes of different weight differ in the pattern of germination. Thus Mogie *et al.* (1991), working with *Taraxacum hamatiforme,* found a very clear tendency for achenes below 0.6mg to germinate shoot first (with the root emerging 1-3 days later), and for heavier achenes to germinate root first (with cotyledons emerging 1-3 days later). However, when Sheppard (1993) attempted to determine the extent to which this pattern occurs among achenes buried in soil (experiments conducted by Mogie *et al.* were on moist filter paper), the results were inconclusive.

The experiment described here does not attempt to answer the question 'root or shoot first?' Instead it attempts to quantify the amount of plant resources allocated to root and shoot during the initial stages of seedling growth and to see if there are differences in allocation linked to achenes germinating either root first or shoot first.

Materials and Methods

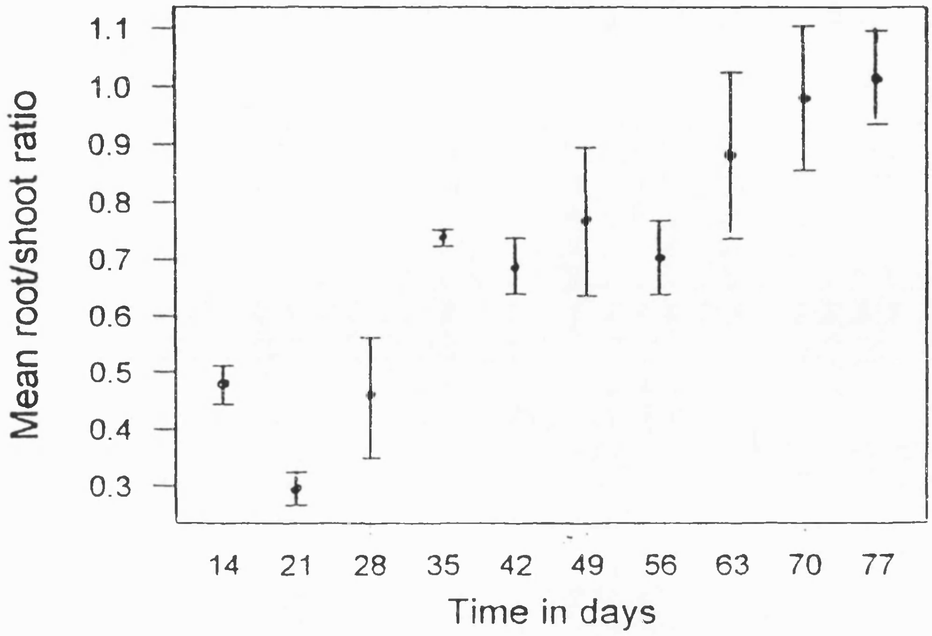
One capitulum from W3 and one from M2 were used. These were obtained from the same plants used in the previous experiment. Achenes were individually weighed and were classified into 2 size classes: <0.5mg and >0.7mg (weights are fresh weight). Forty achenes for each size class for each clone were selected at random and were germinated on Vermiculite in plastic pots under a mist unit (as described above). The seedlings were transplanted into the NFT channels (as described above).

At weekly intervals, starting when the seedlings were 14 days old, four seedlings from each size class for each clone were removed from the channels. The roots of the seedlings were blotted dry and separated from the rest of the plant. In young seedlings the cut was made at the base of the cotyledons. In older plants it was made just above the root crown. Each portion of each seedling was weighed. The ratio of fresh root weight to fresh shoot weight was calculated by dividing root weight by shoot weight. A value of less than 1 indicates that a greater proportion of resources is allocated to shoot growth. A value greater than 1 indicates that a greater proportion of resources is allocated to root growth. The experiment was terminated at 77 days when the temperature of the nutrient solution rose above 30^0C.

Changes in root and shoot allocation over first 70 days of growth

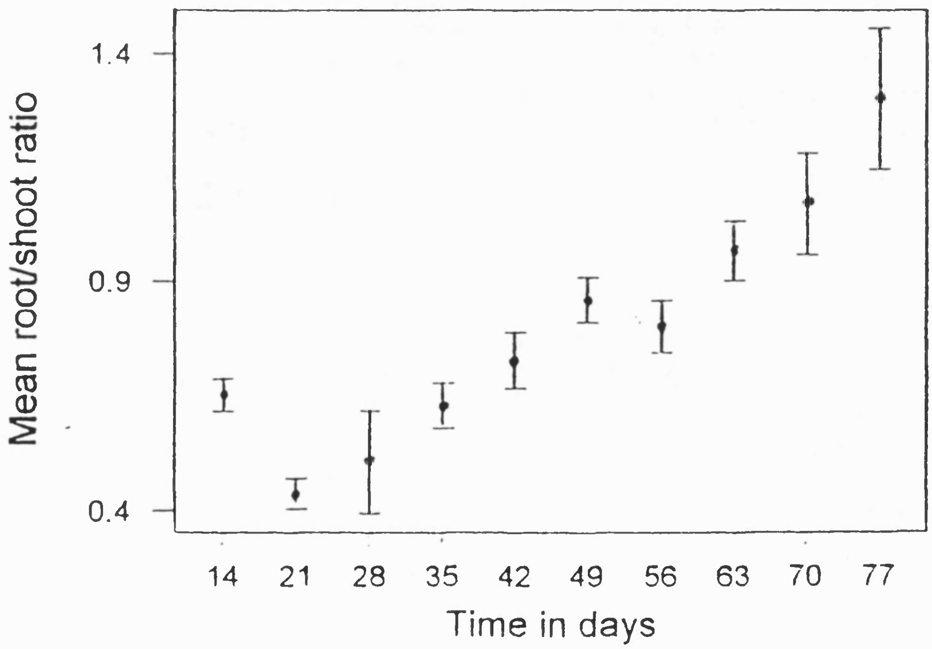
Figure 11 – (i)

Change of root/shoot ratio with time for M2 achenes <0.5mg fresh weight

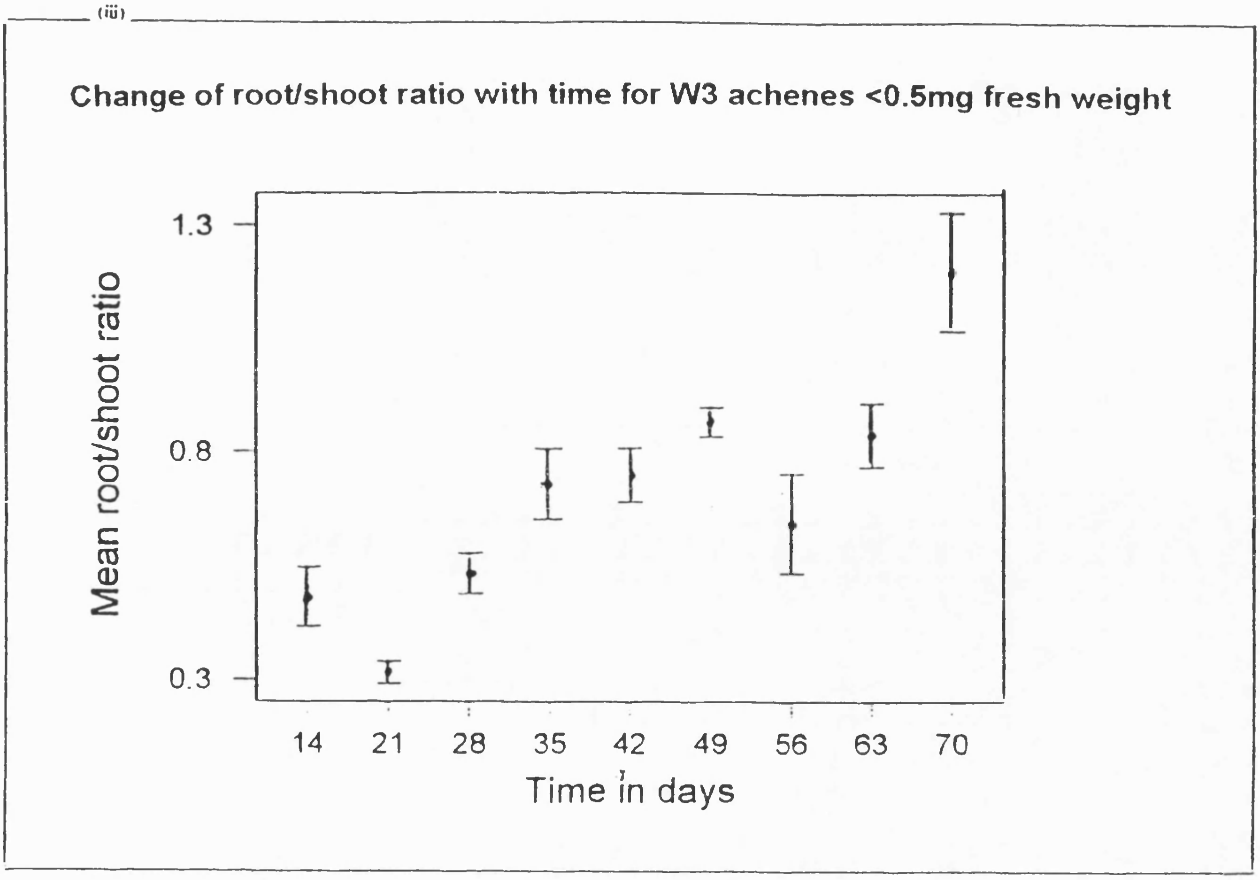


(ii)

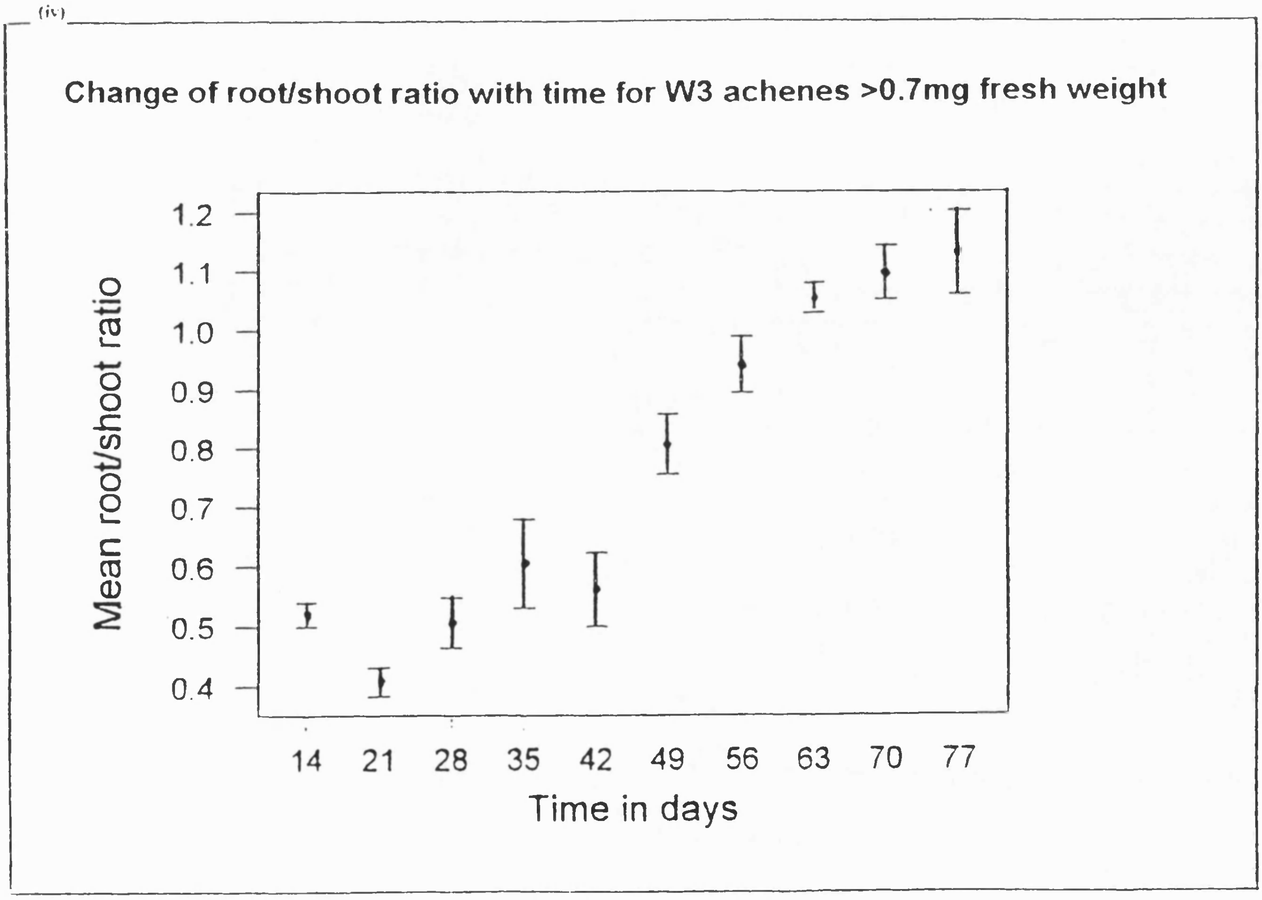
Change of root/shoot ratio with time for M2 achenes >0.7mg fresh weight



(iii)


Change of root/shoot ratio with time for W3 achenes <0.5mg fresh weight
Mean root/shoot ratio
1.3
0.8
0.3
14
21
28
35
42
49
56
63
70
Time in days

(iv)


Change of root/shoot ratio with time for W3 achenes >0.7mg fresh weight
Mean root/shoot ratio
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
14
21
28
35
42
49
56
63
70
77
Time in days

Results

The results are shown as a plot of mean root/shoot ratio against time with the error bars included (see Figure 11 (i)-(iv)). It can be seen that all seedlings have the same allocation pattern irrespective of the size of achene from which the plant germinated. There is a 'dip' at 21 days indicating a lower ratio and therefore more allocation to shoot growth before more resources are channelled into root growth which shows a steady increase with time. W3 (<0.5mg) and M2 (>0.7mg) also show another fall in ratio at 56 days followed by a steady increase in the ratio up to the end of the experiment when the ratio is greater than 1. This final ratio indicates that more of the available resources are allocated to root growth.

Discussion

Although I have reported on the constraints imposed by destructive sampling, there is no other way to conduct an experiment into root/shoot ratio. To assess root and shoot weight independently, the plant has to be destroyed. However, I have been careful not to connect the points on the graphs in Figure 11. Each mean ratio should be seen as an isolated point in time. Nevertheless each size class for each clone does produce a similar plot. This may be a reflection of the environmental conditions at the time of assessment but it does show that both clones and both sizes (weight classes) of achenes show similar patterns of allocation in response to prevailing conditions. There is a tendency for the shoot to take the greater share of resources at the start of growth. Young leaves are resource 'sinks' because they cannot fix enough carbon to support their growth. However, the status of a leaf progressively changes from sink to source as its photosynthetic capacity increases during its ontogeny (Hay and Walker 1989). Overall, it seems that at the start of plant growth, leaves expand rapidly to enable photosynthesis to occur at a rate which results in leaves being sources rather than 'sinks'. Once this stage is achieved root growth can increase. In this experiment, the nutrients were not restricted and so root growth could proceed at an optimum rate.

4.3 'Leaf Turnover Experiment' : a means of looking at plant growth by considering the plant as a population of leaves.

Introduction

Traditional growth analysis techniques, which have dealt with changes in plant weight and leaf area, have contributed a great deal to the understanding of plant growth. However, there are other ways of measuring plant growth that are not addressed by these techniques. These include measures of the pattern of leaf turnover. Here, a plant is considered to comprise, in part, a population of leaves. Each leaf has a life cycle, comprising birth, juvenile phase, mature phase (during which resources are contributed to the birth of other leaves and ultimately to flowering and seed set), senescence and death. The leaf population at any point in time is the 'births' minus the deaths. A description of the growth of a plant as a population of parts needs to quantify the births and deaths of these parts. Bazzaz and Harper (1977) used colour coded rings slipped onto *Linum usitatissimum* plants to separate each cohort of new leaves. They assessed the plants at intervals of 3 days using a different coloured ring each time. The leaves between successive rings were counted and were treated as cohorts. The death of leaves was quantified by recording the date at which a cohort of leaves began to die and the date at which they had all died. This procedure was adapted for the experiment reported here. Coloured plastic rings could not be used on *Taraxacum* plants as they consist of flat rosettes of leaves. Instead, coloured thread was used, passing it through the main leaf midrib with a fine sewing needle. Ford (1982) investigated the demography of 2 agamospecies of *Taraxacum* which co-existed in the same sand dune habitats and found that the 2 species had quite distinct leaf birth rates. Leaf birth rates have been found to be cyclical in pattern (Cox and Ford 1987) and are affected by external factors such as light intensity, temperature and the availabilty of water and nutrients (Ford 1982). The assessment of the birth and death of leaf cohorts is sometimes referred to as 'leaf turnover' and it can be described by the equation : $N(t+1)=Nt + B-D$, where Nt is the number of leaves present at time t, $N(t + 1)$ is the number present at time $(t + 1)$, B is the number of new leaves produced, and D is the number of leaves dying in the interval $(t + 1) - t$.

Materials and Methods

Germinated achenes from the initial experimental material (see section 2.1) were selected to be representative of both clone and initial achene weight. (see Table 20 for a summary). In total, 14 seedlings were selected from 6 clones and were repotted (from the trays in which they had germinated), into a known volume (2l) of Levington M2 compost in individual 18cm pots. This pot size was used in order to avoid the need for repotting during the experiment. Each seedling was individually labelled and the pots were randomly arranged (using random number tables) on a bench in a greenhouse maintained on a daily cycle of approximately 16h at 16°C and 8h at 8°C. The experiment was conducted across seasons so that the ambient light varied.

The experiment commenced in February 1992 when the first cohort of two true leaves were marked, the plants being 23 days old. One plant (M5/105) had produced three true leaves at this age. The leaves were marked by sewing a fine coloured cotton thread through the main midrib of each leaf in the cohort. Although this caused a small hole where the thread passed through the tissue, no additional necrosis of leaf tissue due to marking occurred throughout the entire experiment. Cohorts were marked every three days using a different thread to enable successive cohorts to be identified. At least 30 different colours of thread were used. The date of 'birth' (when new leaves were visible) of each cohort and the number of leaves marked were recorded.

Table 20

Relationship between clone, plant code and fresh achene weight from which plant was grown.

Clone	Achene number	Fresh achene weight in mg
S1	62	0.7093
	75	0.7701
S2	23	0.3646
	78	0.6466
	142	1.0158
S4	55	0.6613
	69	0.7111
S5	33	0.4183
	43	0.5249
W2	63	0.6477
	81	0.769
M5	75	0.9415
	97	0.9745
	105	0.9923

NB In this experiment plants are referred to by a code: eg S1/62, M5/105. The first two characters refer to the clone number. The figures after the stroke refer to the achene number. When achenes from the original material were weighed prior to initial germination all achenes for each clone were ordered in ascending achene weight. Thus S1/62 refers to achene number 62, fresh weight 0.7093 mg of clone S1.

The date of onset of mal-symptoms and the date of complete death of each cohort were also recorded. (A leaf was considered to be dead when it was brown in colour, brittle in texture and easily removed from the rosette.) From 55 days onwards (cohort eight), all plants showed signs of secondary rosettes appearing from the root crown. It was impossible to determine from which rosette leaves had issued, and so new leaves were considered to belong to the same cohort irrespective of rosette. Onset of flowering was also recorded for each plant where applicable. The capitula were collected in sequence and the achenes counted and weighed to determine total and mean achene weight. The experiment was terminated after 521 days.

Results

This experiment generated a great deal of data which has been presented in Table 21 (overleaf) and graphically in Figure 12 (a)-(n) which follows. The latter consists of three graphs for each plant, (i), a plot to show number of leaves per cohort (ii) the duration in days of a cohort against the size of the cohort (i.e. the number of leaves in the cohort) and (iii) a descriptive profile of the plant with cohort size and life span shown on a time scale for the complete experiment (after Fig 1, Bazzaz and Harper 1977).

Table 21:

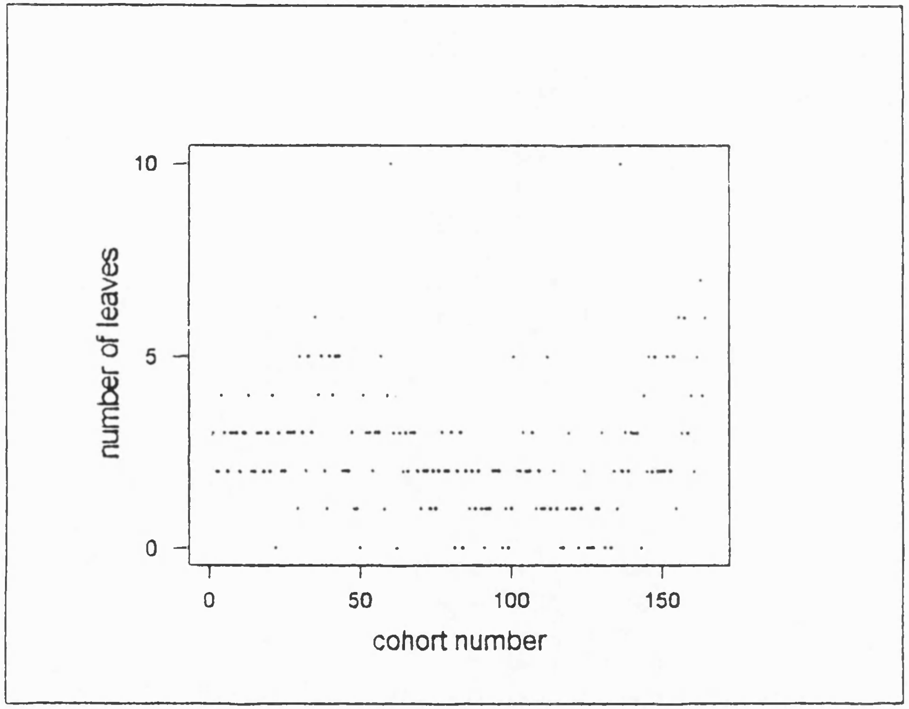
The relationship between achene weight of parent plant, the mean number of leaves per cohort with the range of number of leaves for that plant, the mean duration per cohort (in number of days) again with the range of duration of cohorts for that plant.

Plant code	Achene wt of parent plant in mg	Mean leaves per cohort+/-sem	Range	Mean days/ cohort +/-sem	Range
M5/75	0.9415	3.41+/-0.134	0-10	42.19+/-1.70	0-104
M5/97	0.9745	3.49+/-0.189	0-15	47.95+/-1.91	0-124
M5/105	0.9923	2.47+/-0.134	0-10	40.61+/-1.56	0-97
S1/62	0.7093	3.67+/-0.272	0-19	44.56+/-2.16	0-108
S1/75	0.7701	4.95+/-0.325	0-31	63.0+/-2.45	0-152
S2/23	0.3646	5.09+/-0.303	0-25	55.65+/-1.90	0-124
S2/78	0.6466	3.33+/-0.194	0-15	56.94+/-2.28	0-180
S2/142	1.0158	2.87+/-0.230	0-30	49.0+/-1.69	0-107
S4/55	0.6613	4.53+/-0.225	0-24	43.83+/-1.55	0-98
S4/69	0.7111	4.53+/-0.255	0-21	44.47+/-1.69	0-105
S5/33	0.4183	2.22+/-0.105	0-6	43.3+/-1.44	0-87
S5/43	0.5249	2.41+/-0.126	0-8	43.15+/-1.77	0-148
W2/63	0.6477	5.90+/-0.358	0-38	65.59+/-1.94	0-167
W2/81	0.769	5.38+/-0.348	0-49	51.85+/-1.18	0-115

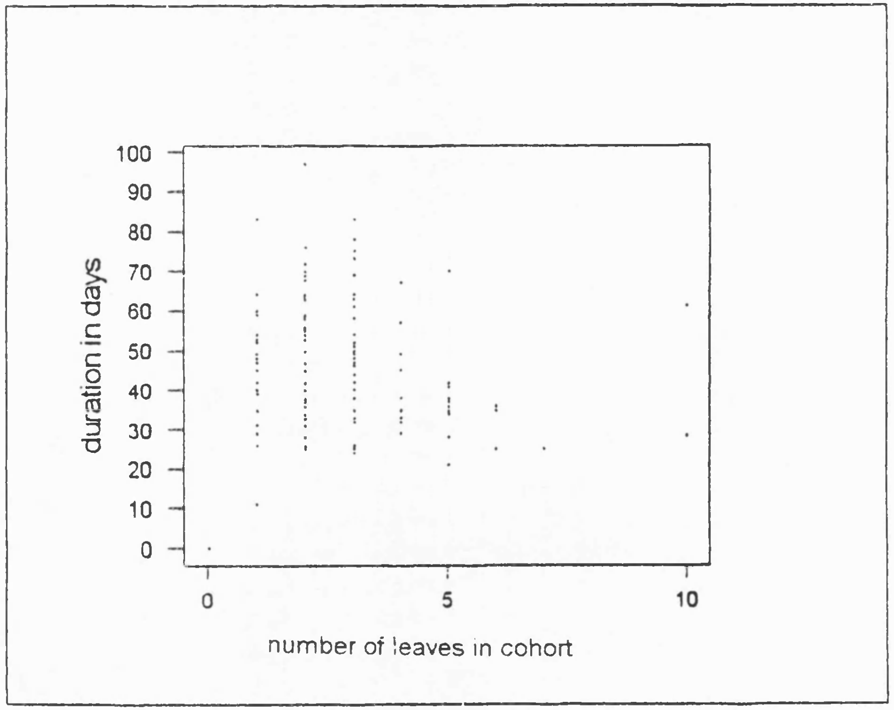
Figure 12 (a)

Results from leaf turnover experiment for M5/105

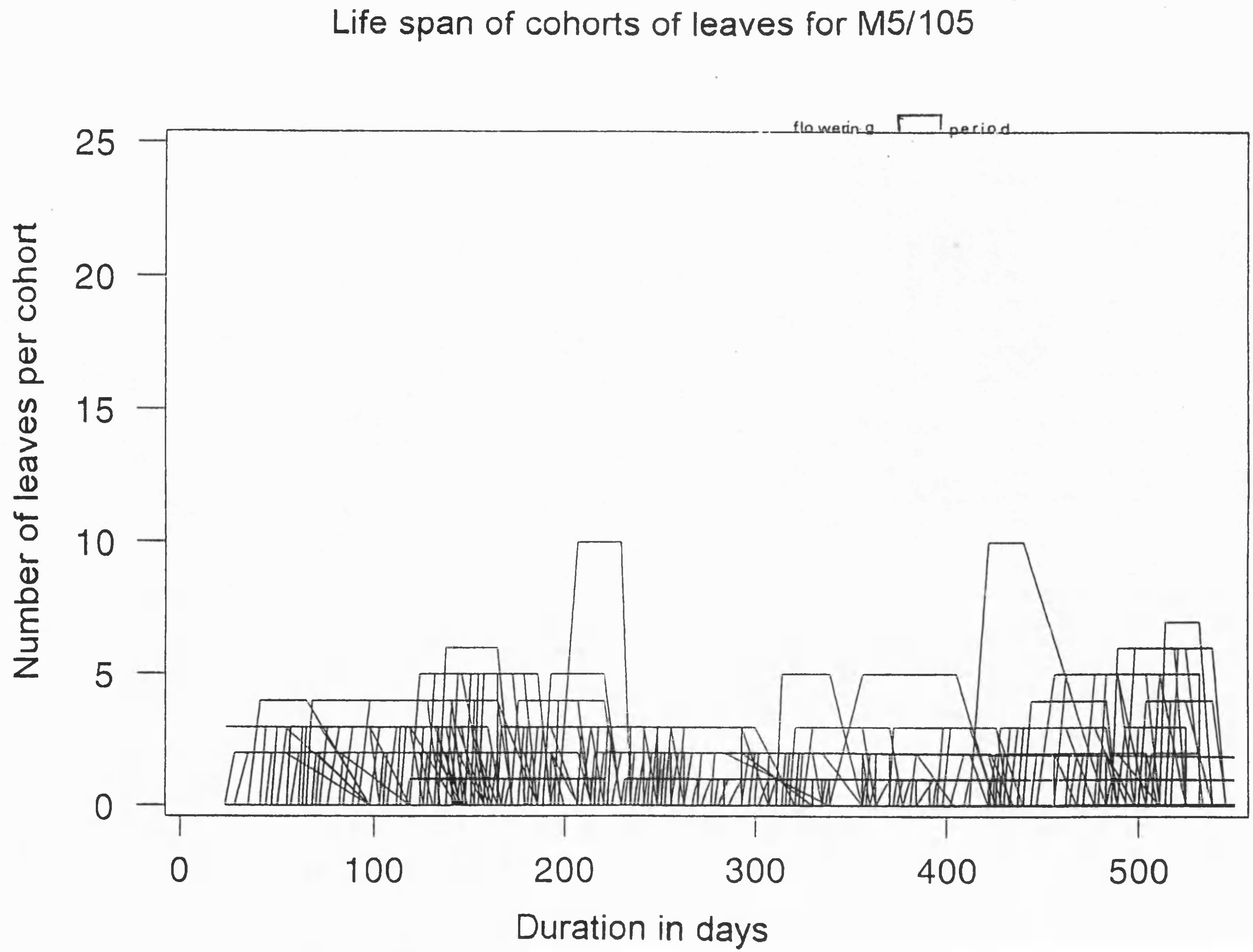
(i) Number of leaves per cohort



(ii) Duration of cohort against number of leaves in cohort

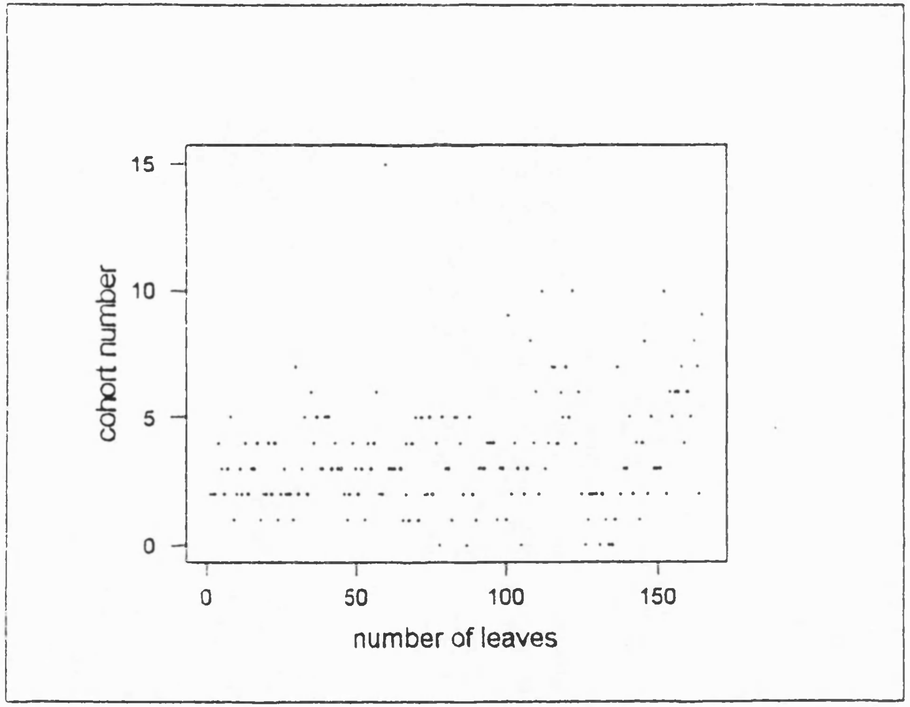


(iii)

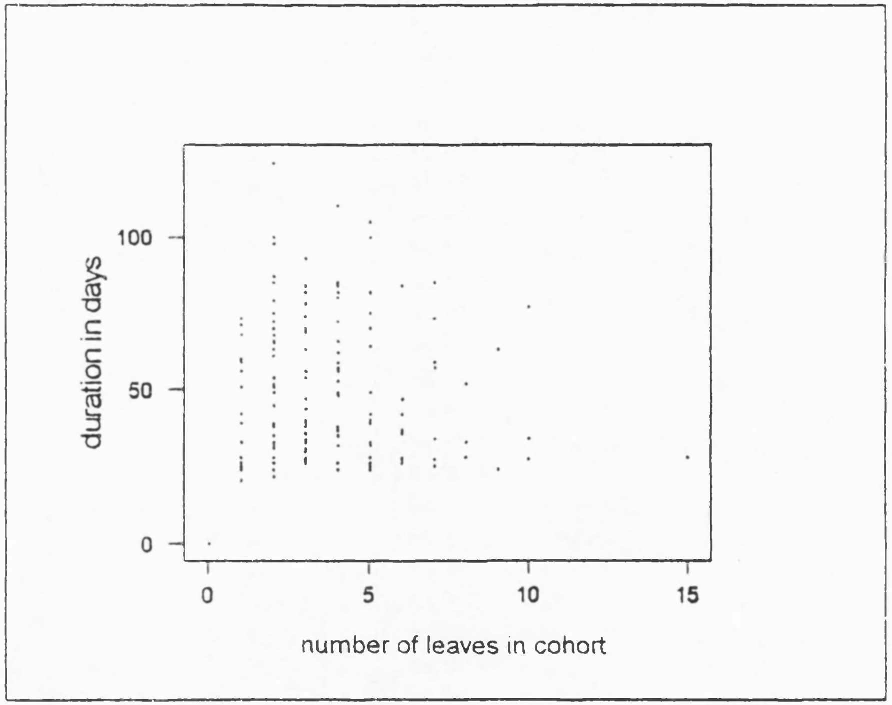

Life span of cohorts of leaves for M5/105
flowering period
Number of leaves per cohort
0
5
10
15
20
25
0
100
200
300
400
500
Duration in days

(b) Results from leaf turnover experiment for M5/97

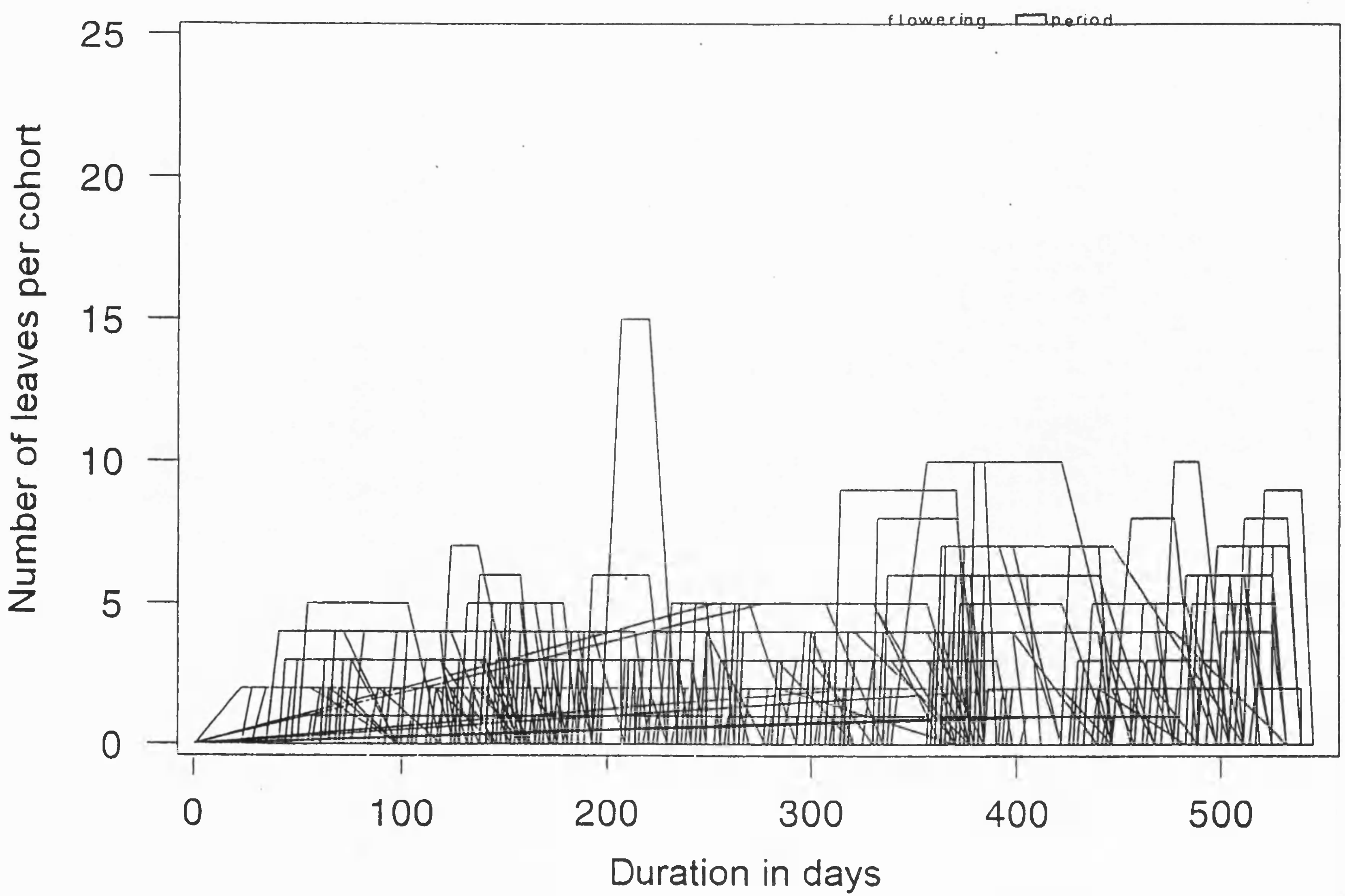
(i) Number of leaves per cohort



(ii) Duration of cohort against number of leaves in cohort

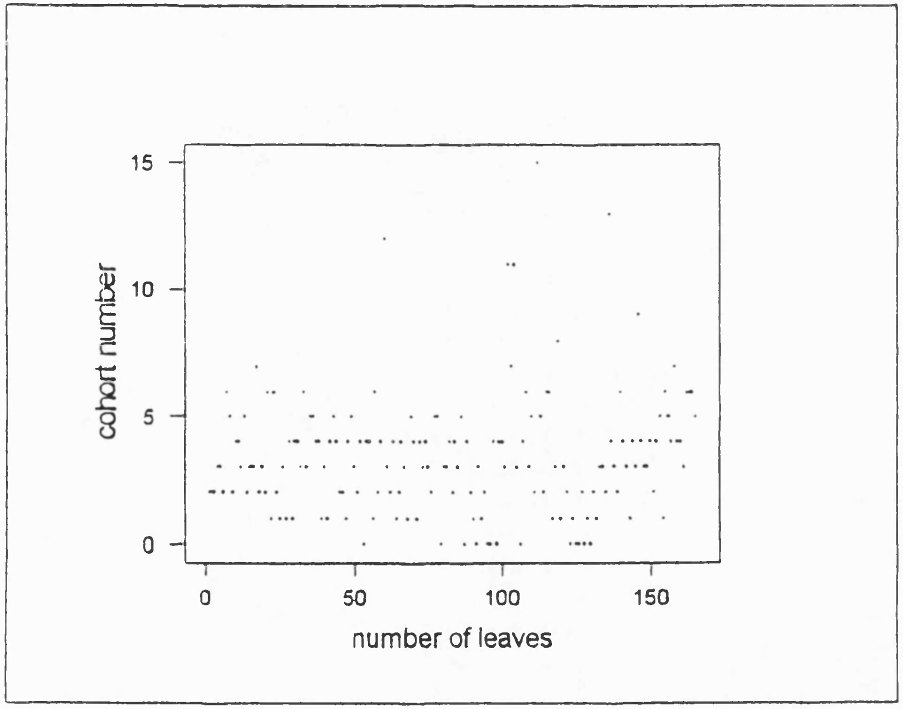


(iii) Life span of cohorts of leaves for M5/97

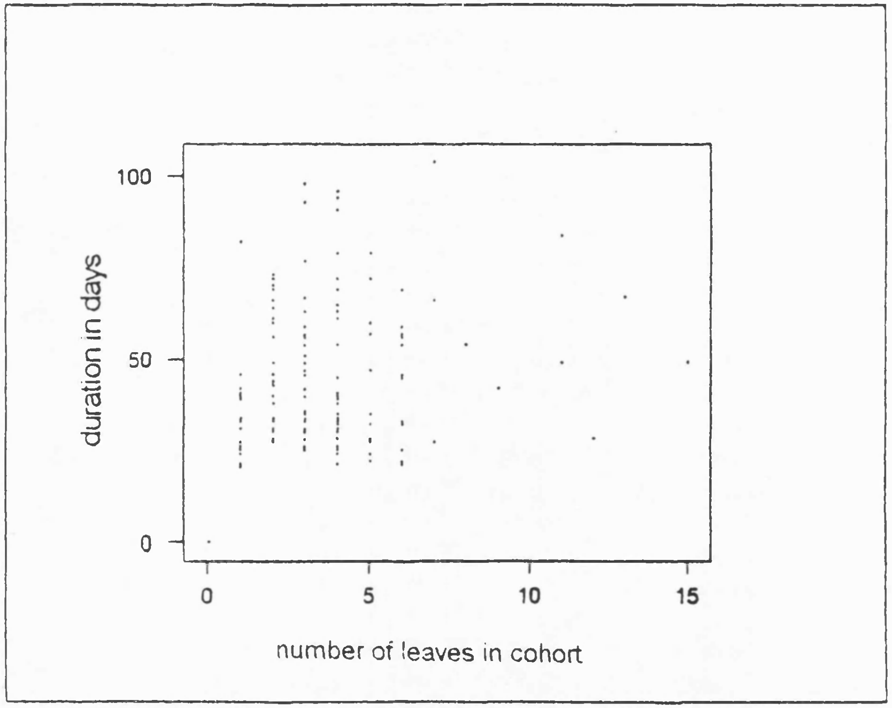


(c) Results from leaf turnover experiment for M5/75

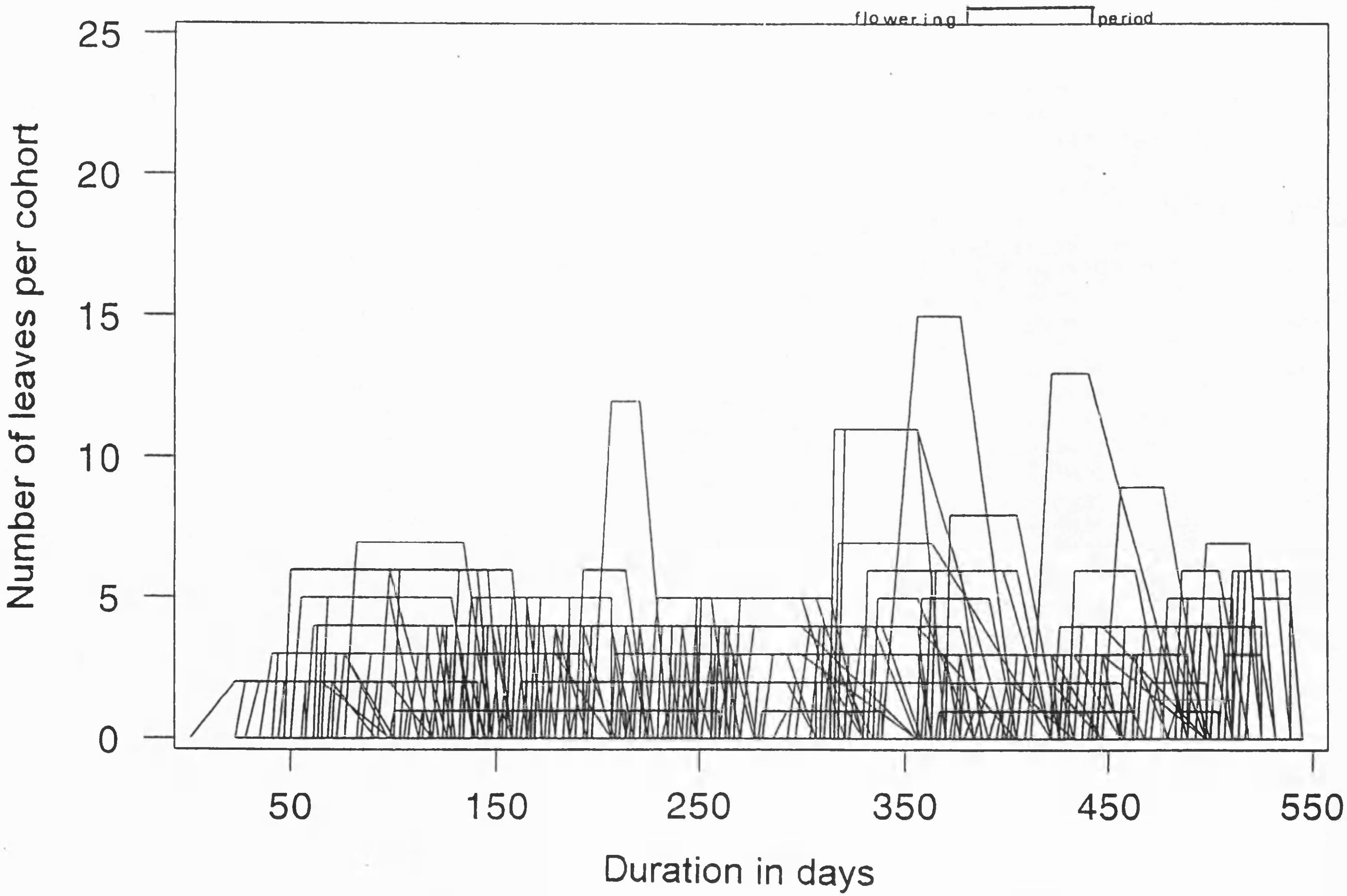
(i) Number of leaves per cohort



(ii) Duration of cohort against number of leaves in cohort

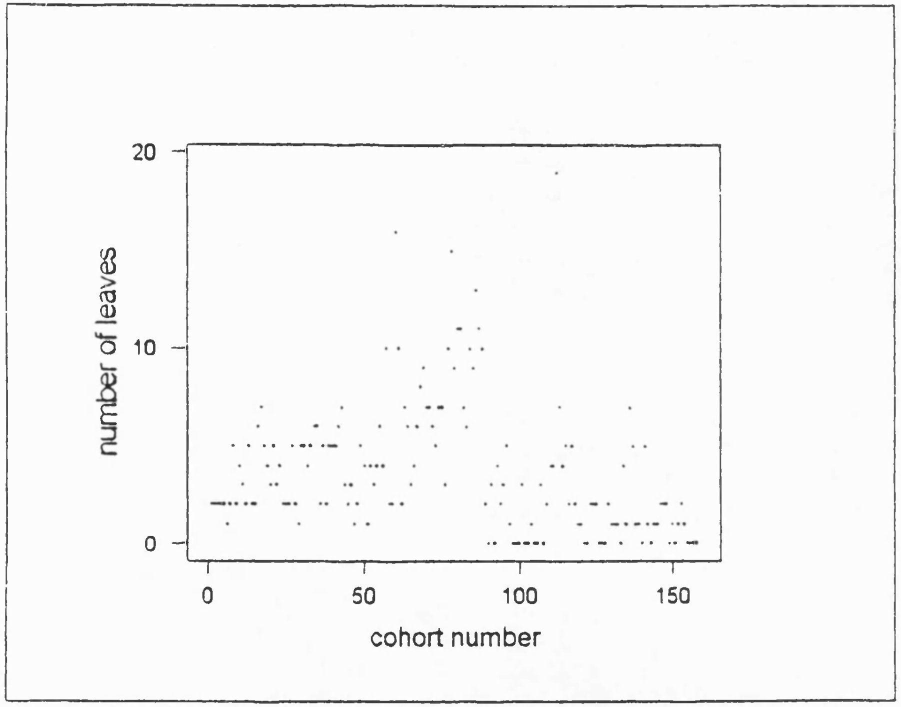


(iii) Life span of cohorts of leaves for M5/75

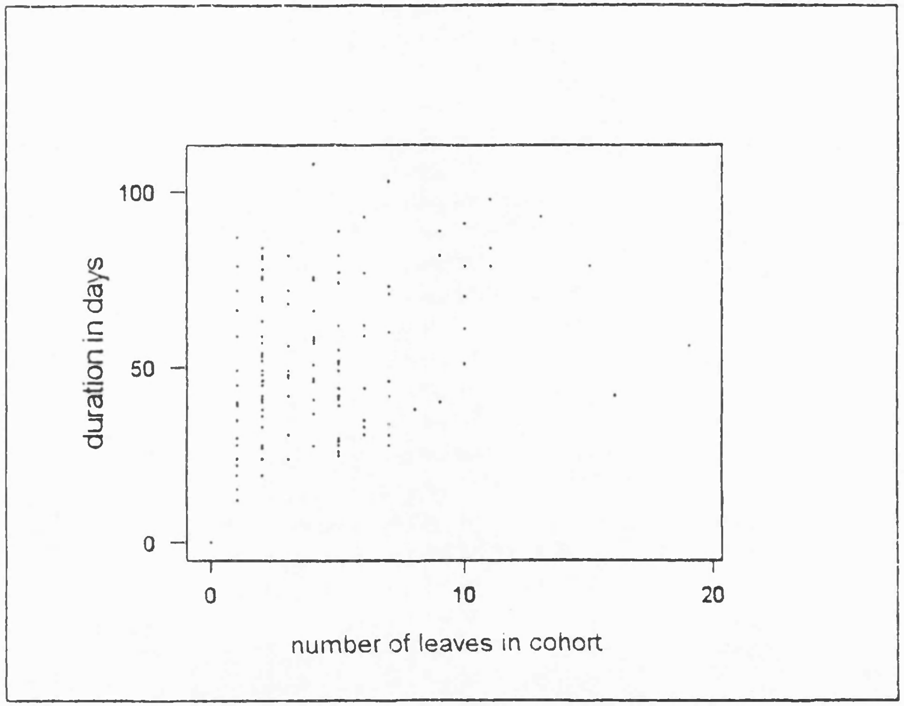


(d) Results from leaf turnover experiment for S1/62

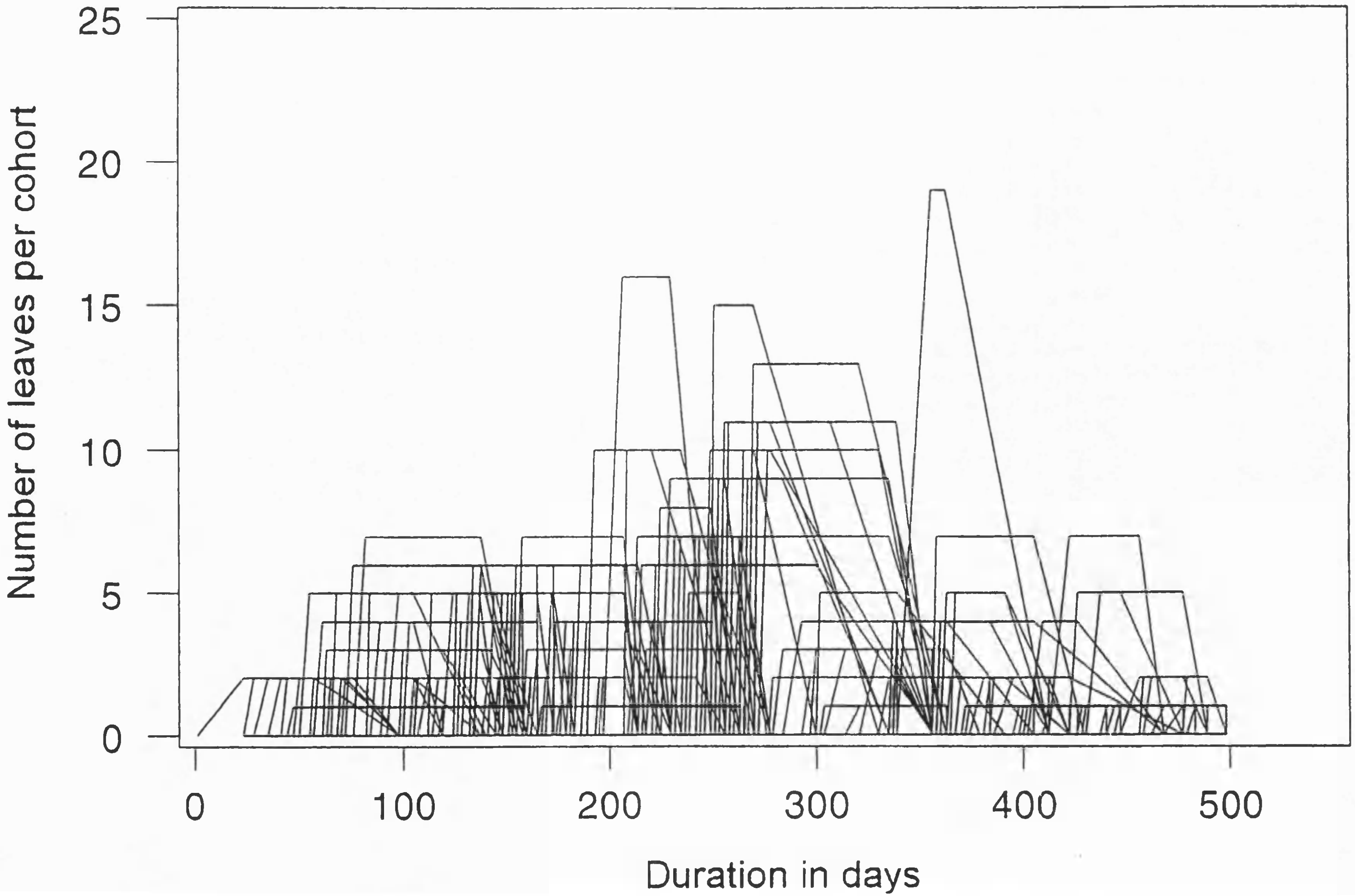
(i) Number of leaves per cohort



(ii) Duration of cohort against number of leaves in cohort

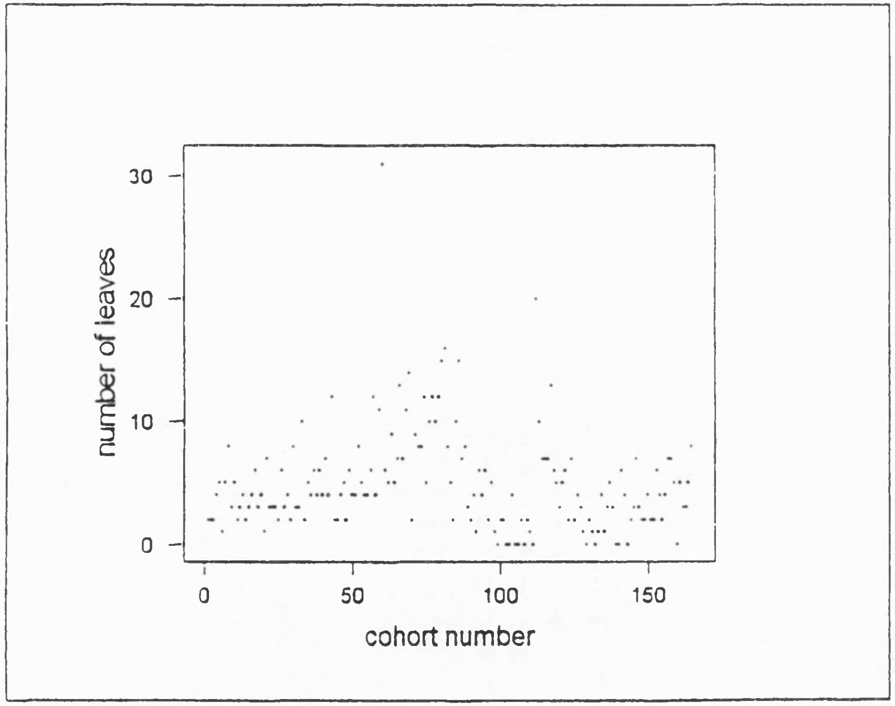


(iii) Life span of cohorts of leaves for S1/62

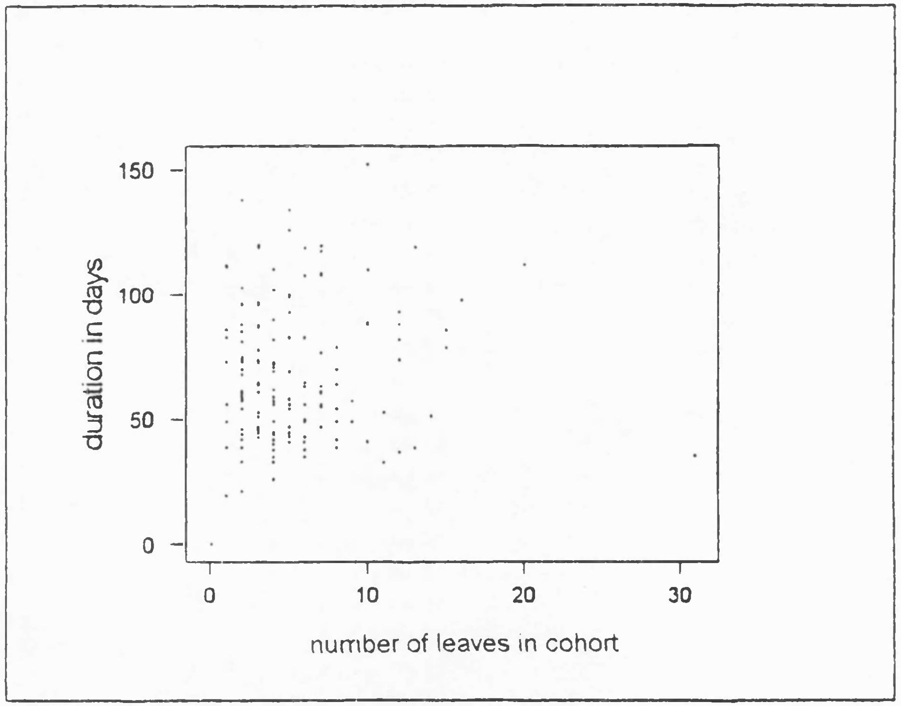


(e) Results from leaf turnover experiment for S1/75

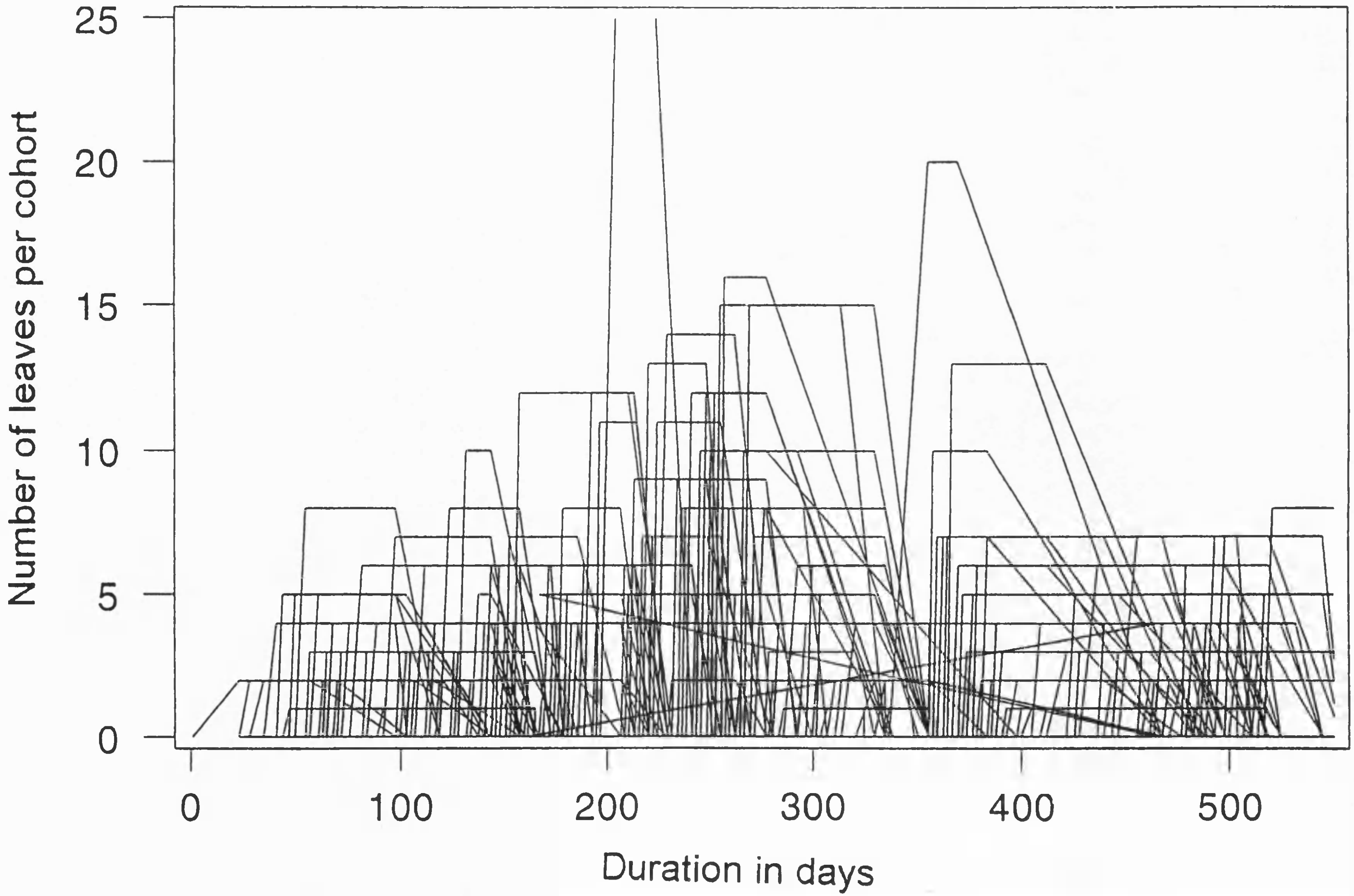
(i) Number of leaves per cohort



(ii) Duration of cohort against number of leaves in cohort

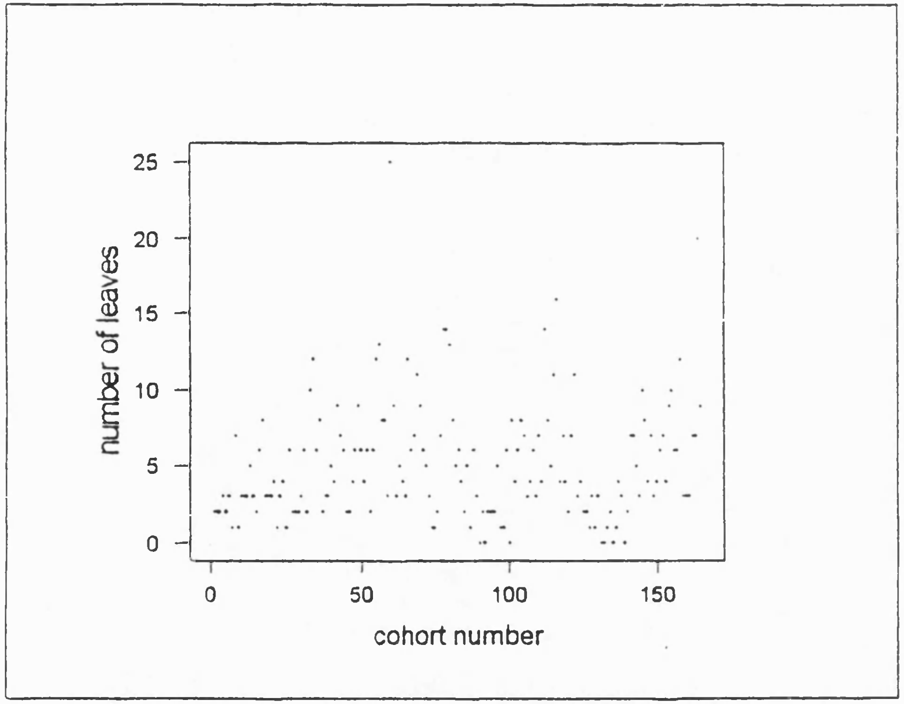


(iii) Life span of cohorts of leaves for S1/75

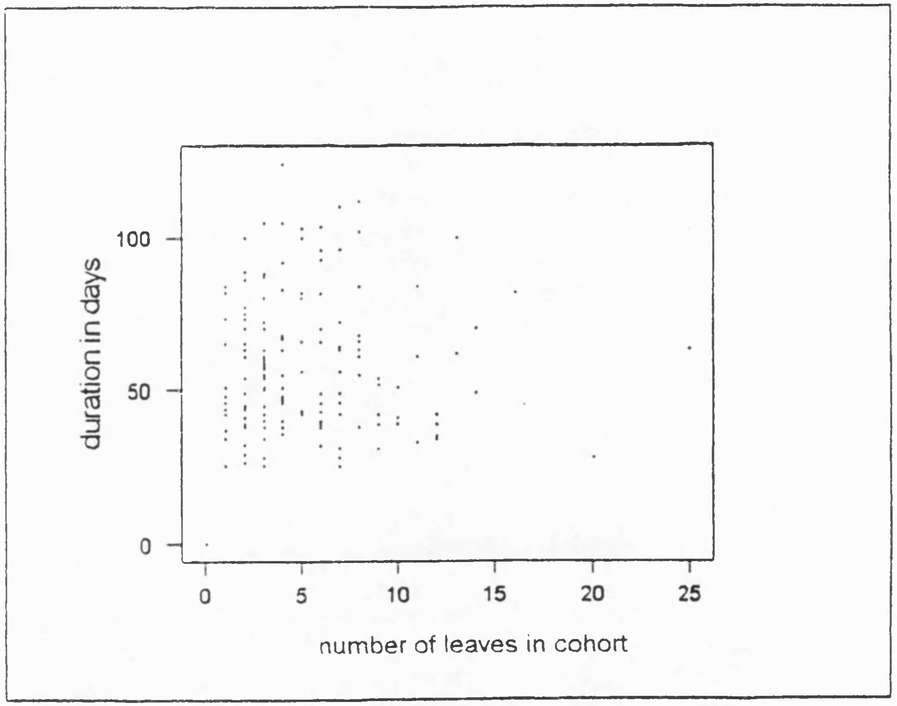


(f) Results from leaf turnover experiment for S2/23

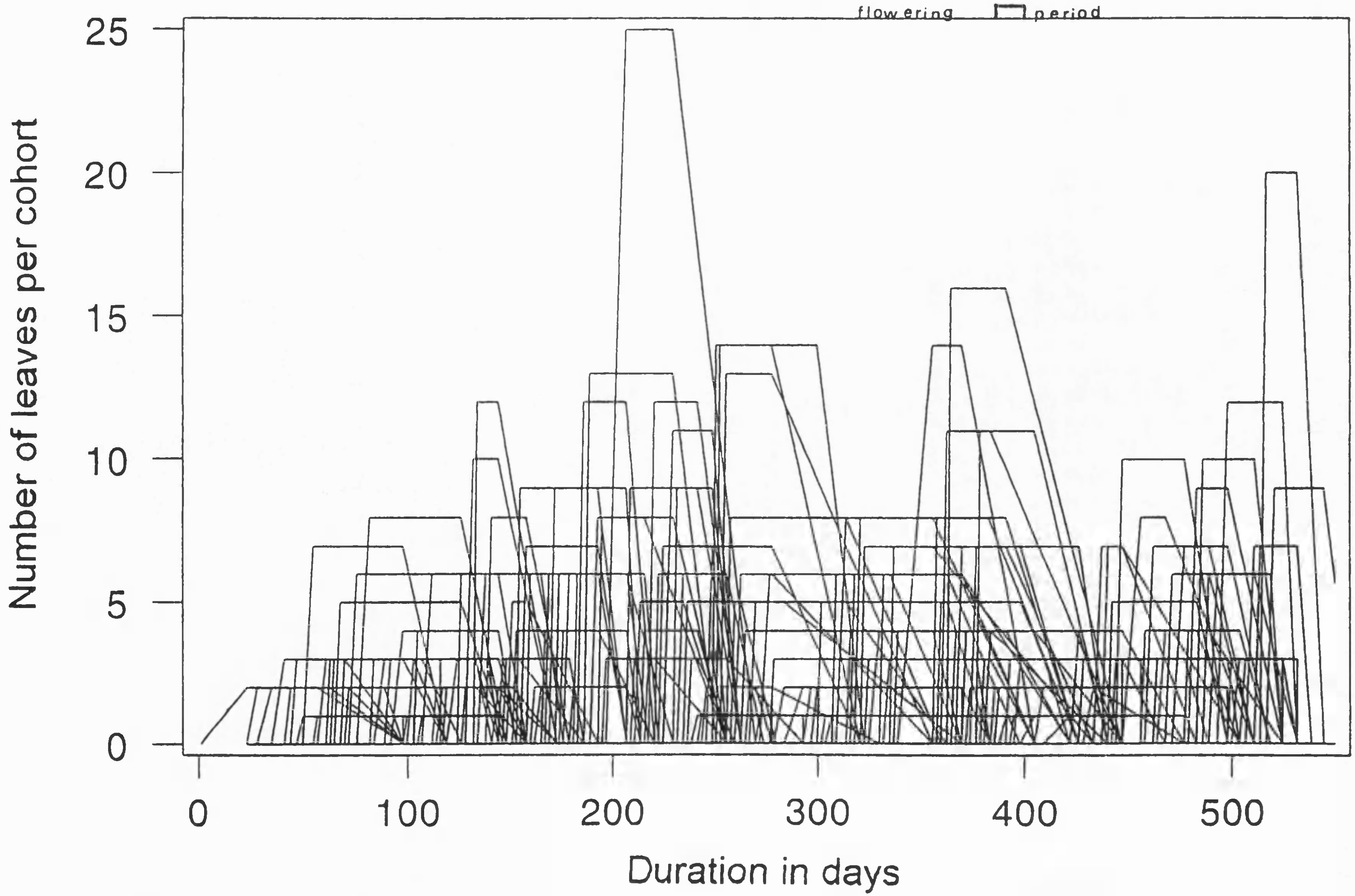
(i) Number of leaves per cohort



(ii) Duration of cohort against number of leaves in cohort

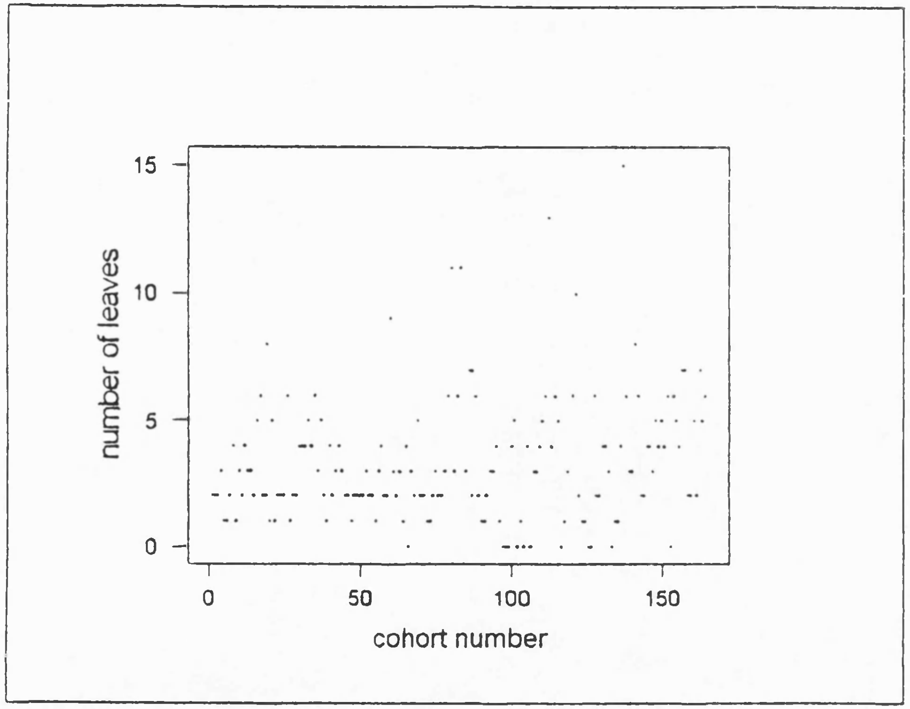


(iii) Life span of cohorts of leaves for S2/23

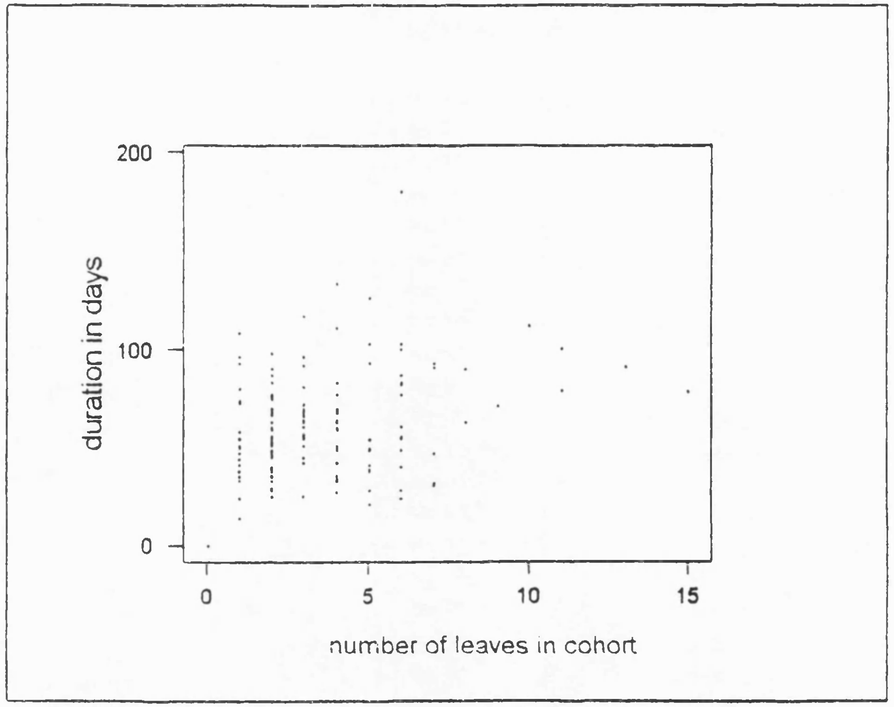


(g) # Results from leaf turnover experiment for S2/78

(i) Number of leaves per cohort



(ii) Duration of cohort against number of leaves in cohort

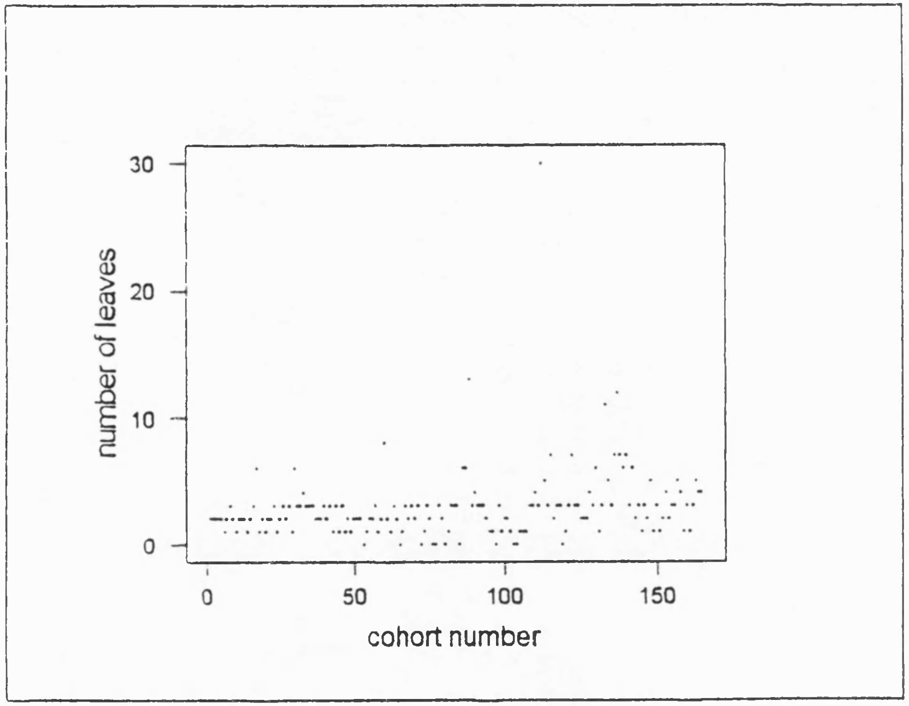


(iii)

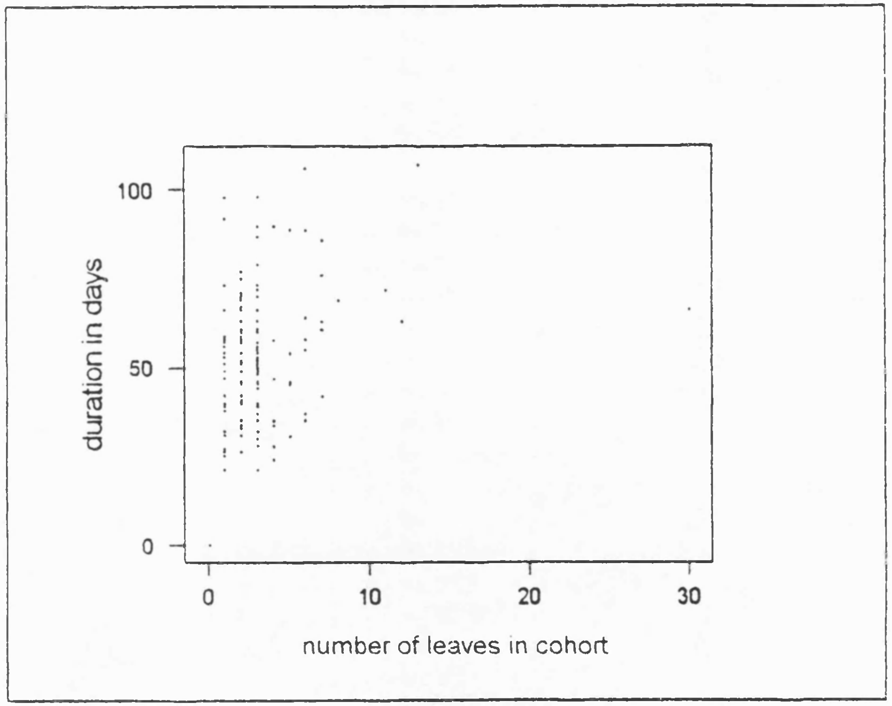
Life span of cohorts of leaves for S2/78
Number of leaves per cohort
Duration in days
0
5
10
15
20
25
0
100
200
300
400
500

(h) Results from leaf turnover experiment for S2/142

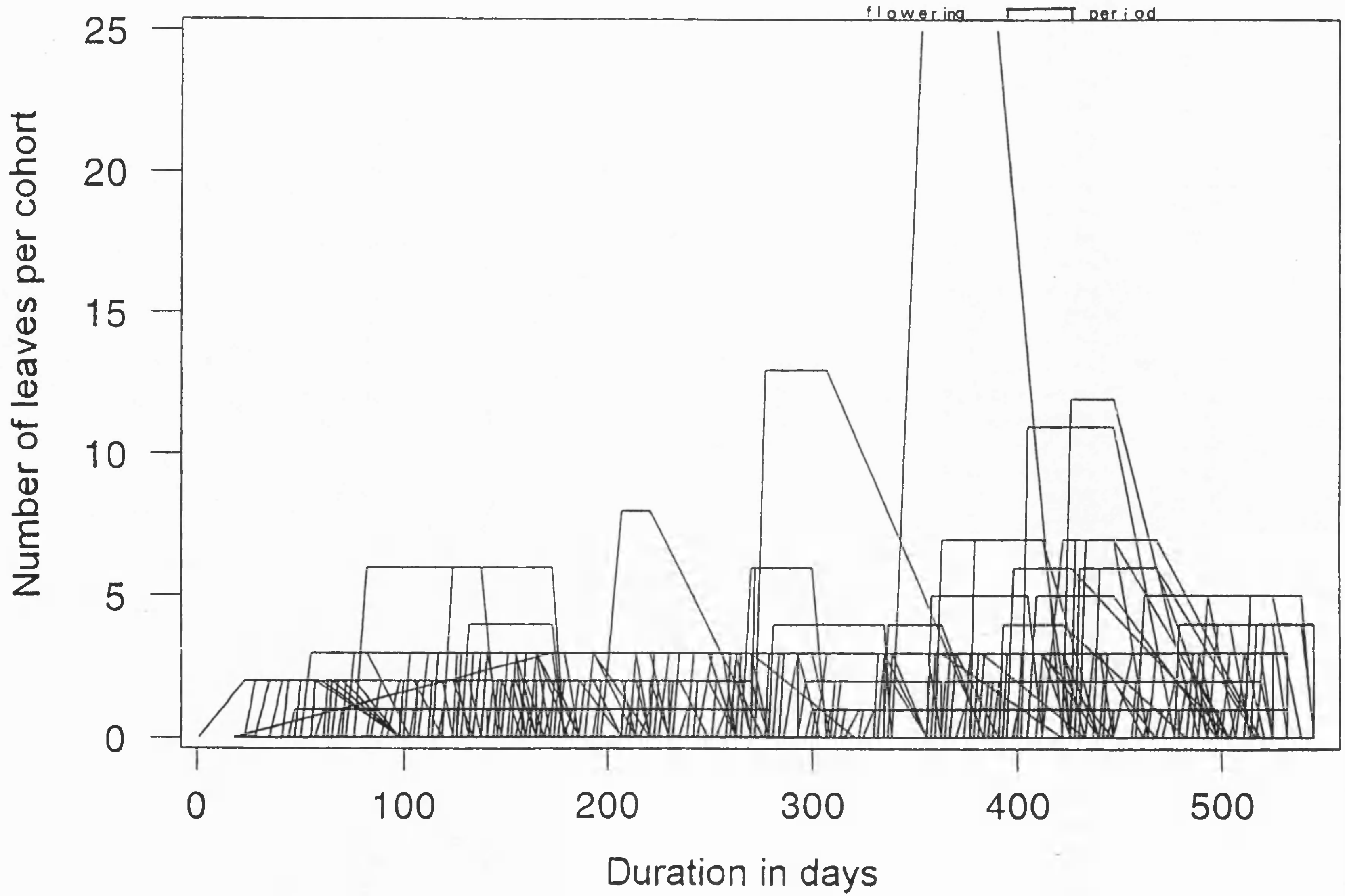
(i) Number of leaves per cohort



(ii) Duration of cohort against number of leaves in cohort

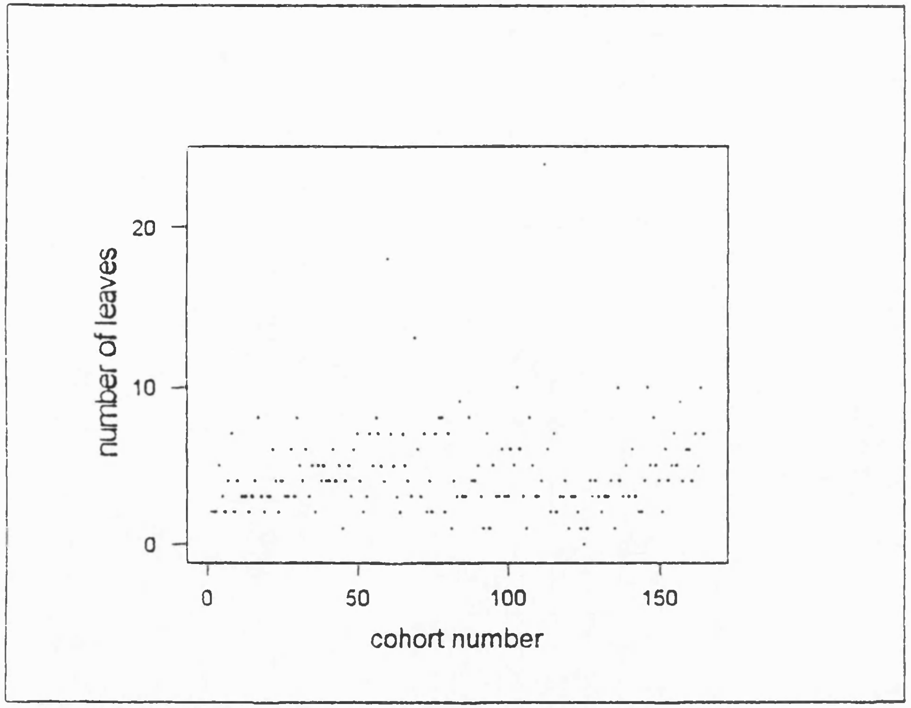


(iii) Life span of cohorts of leaves for S2/142

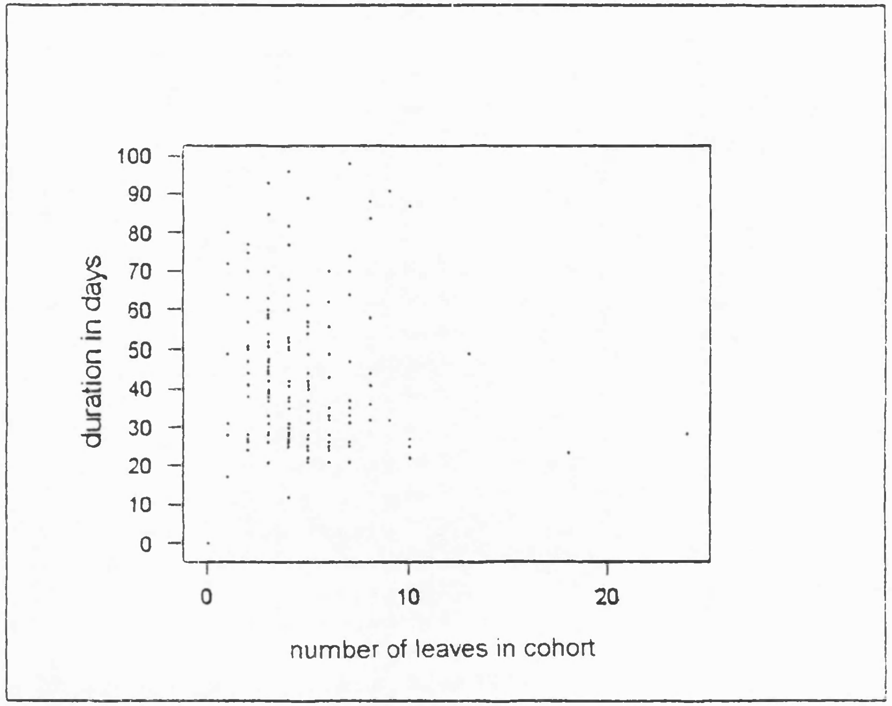


(i) Results from leaf turnover experiment for S4/55

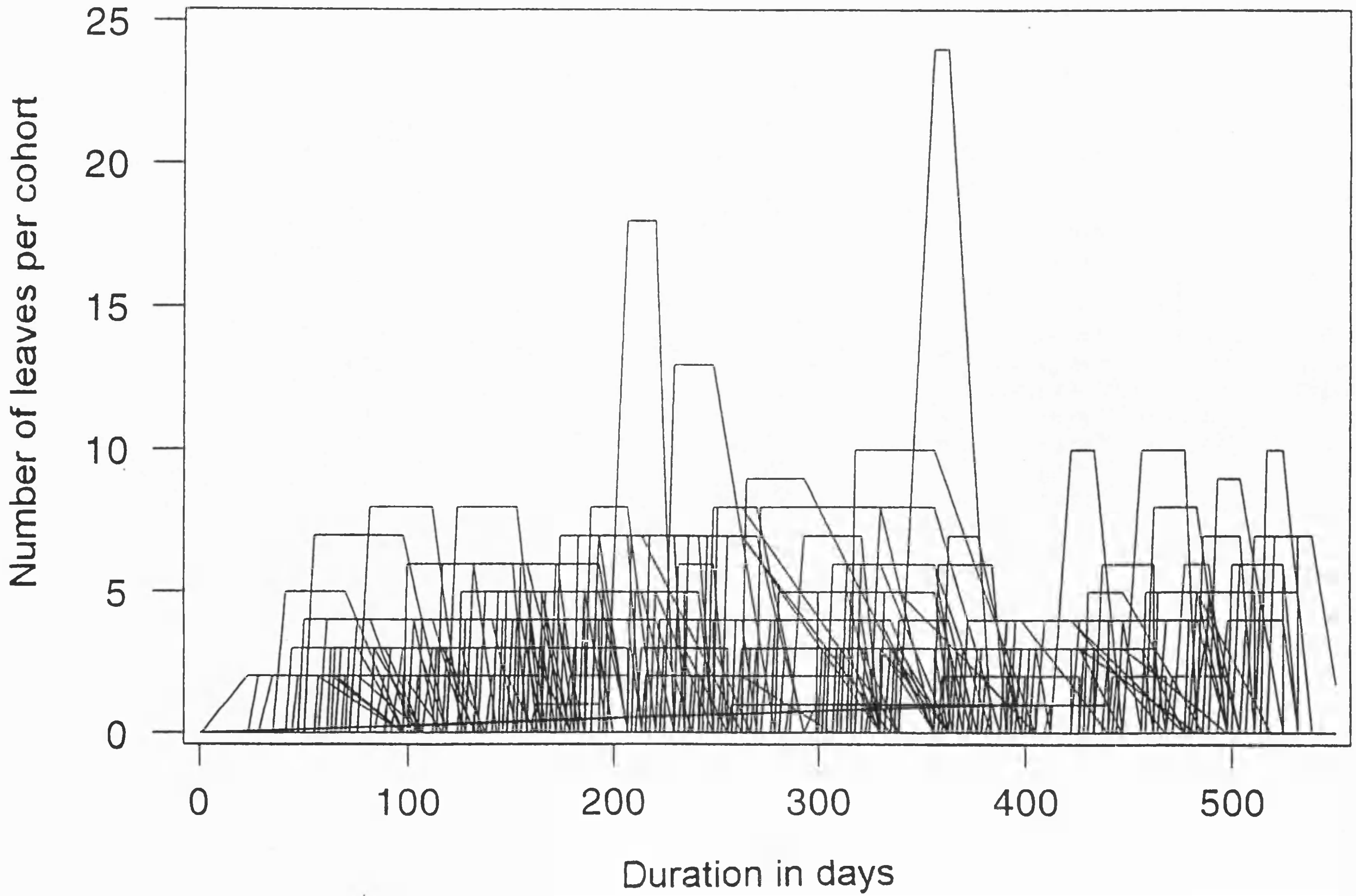
(i) Number of le?ves per cohort



(ii) Duration of cohort against number of leaves in cohort

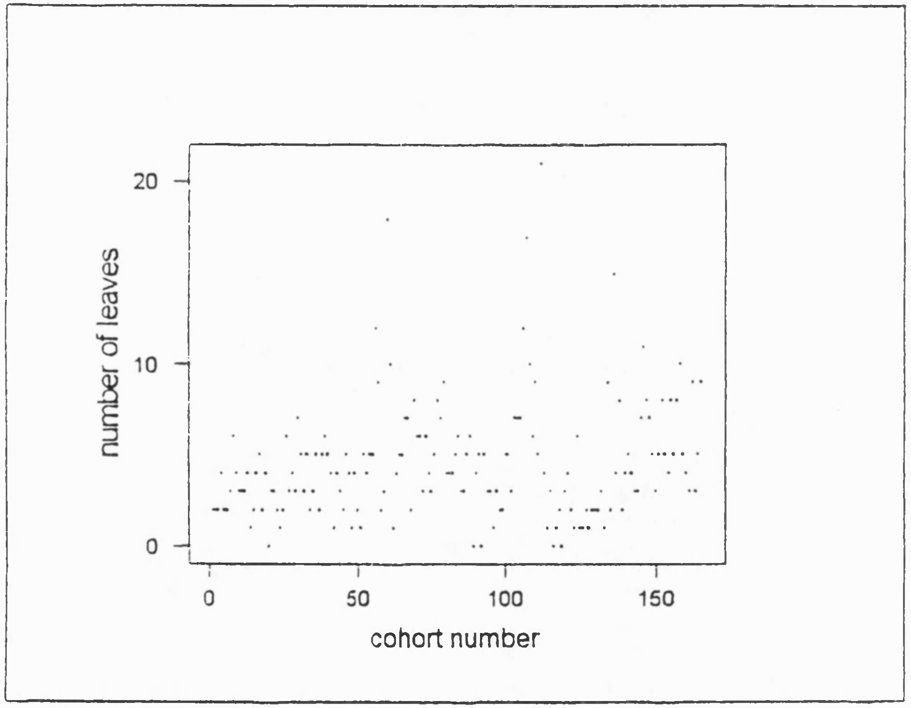


(iii) Life span of cohorts of leaves for S4/55

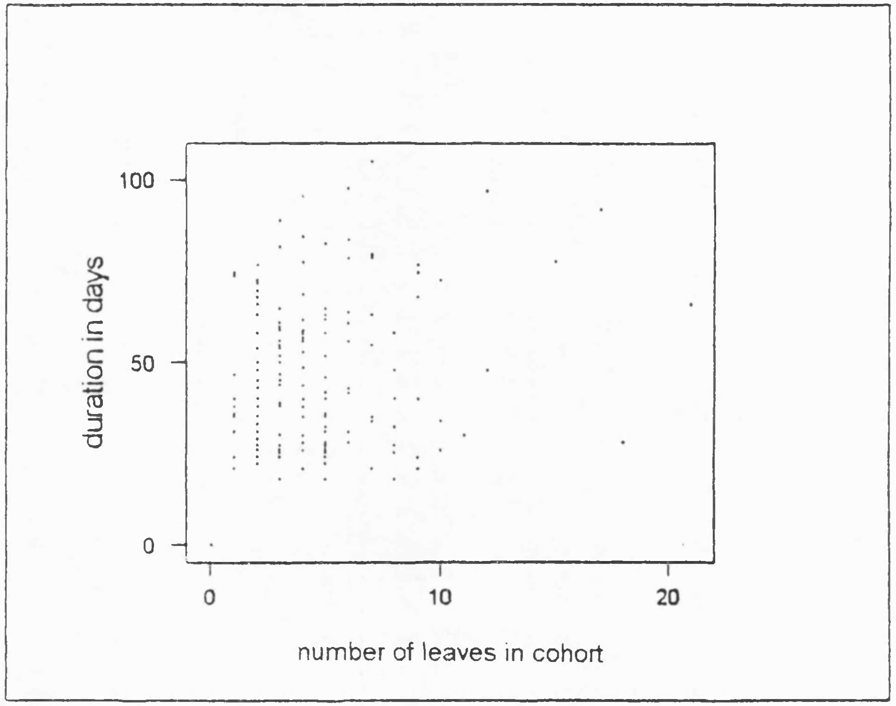


(j) # Results from leaf turnover experiment for S4/69

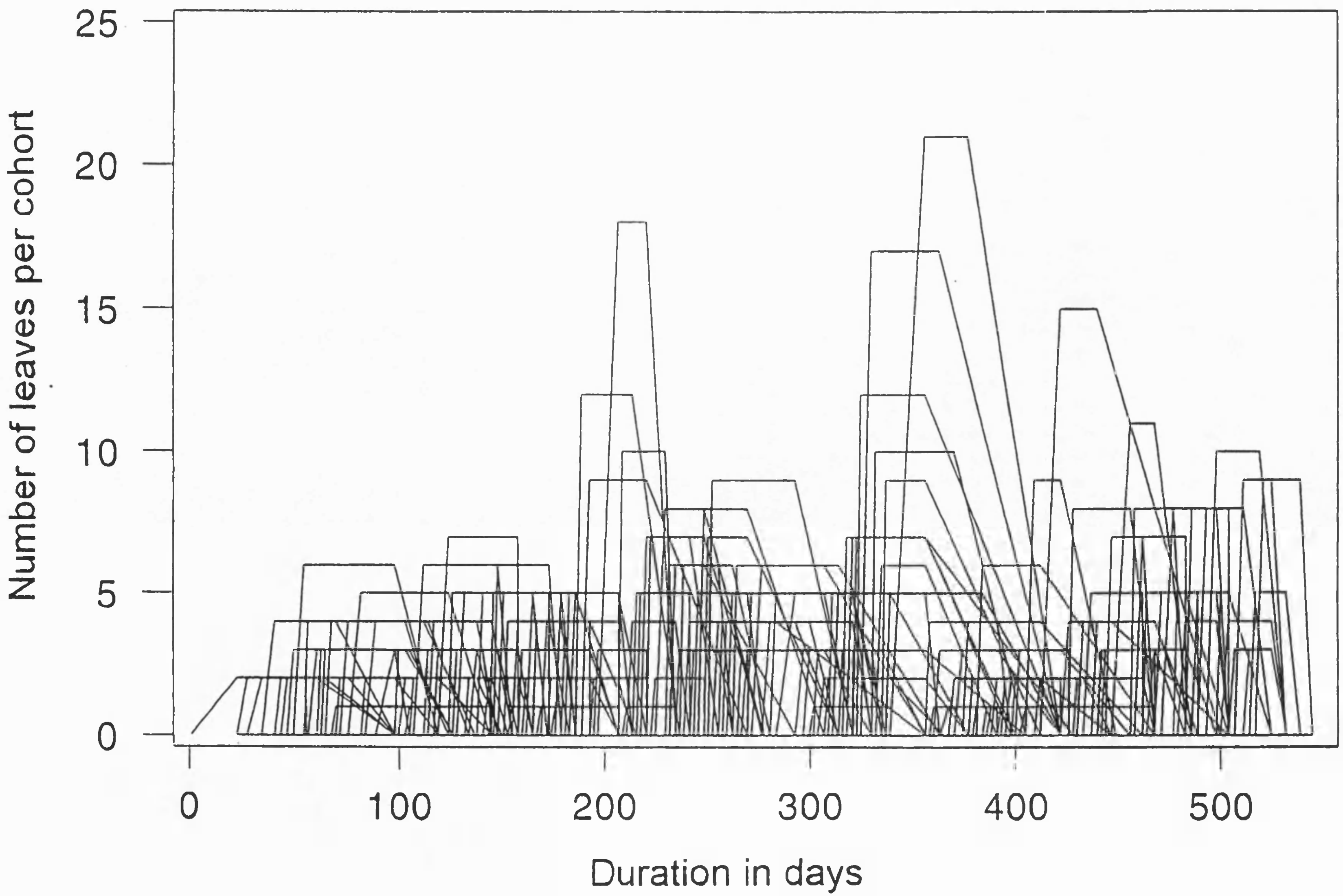
(i) Number of leaves per cohort



(ii) Duration of cohort against number of leaves in cohort

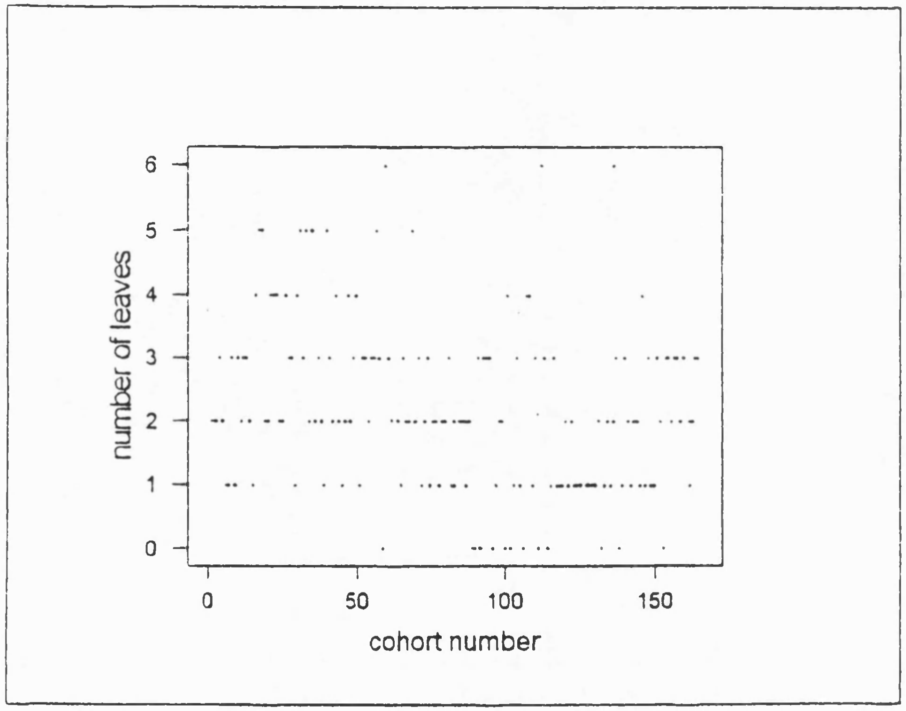


(iii) Life span of cohorts of leaves for S4/69

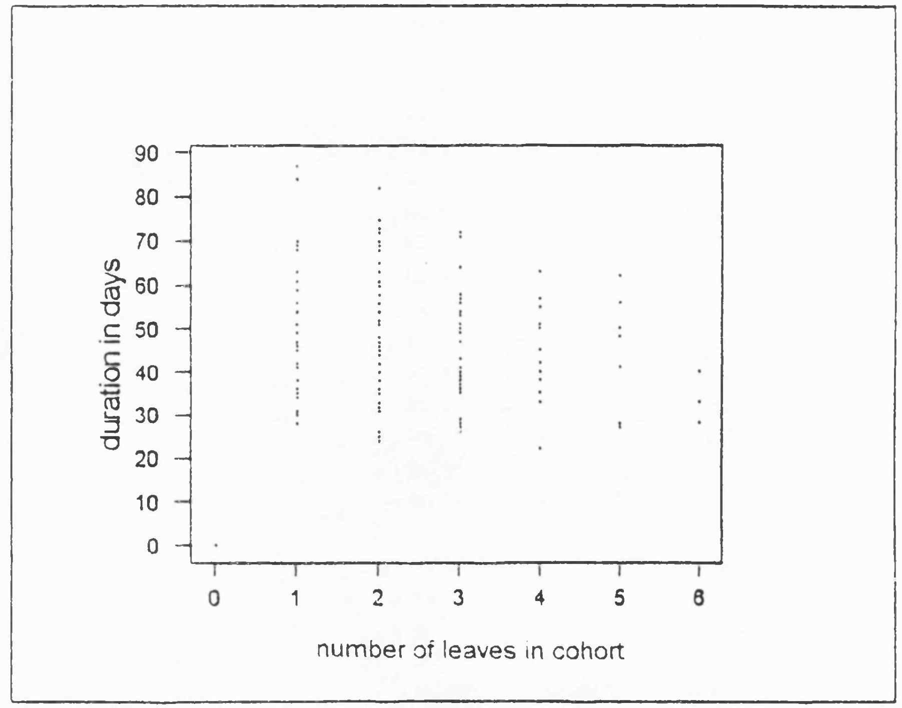


(k) Results from leaf turnover experiment for S5/33

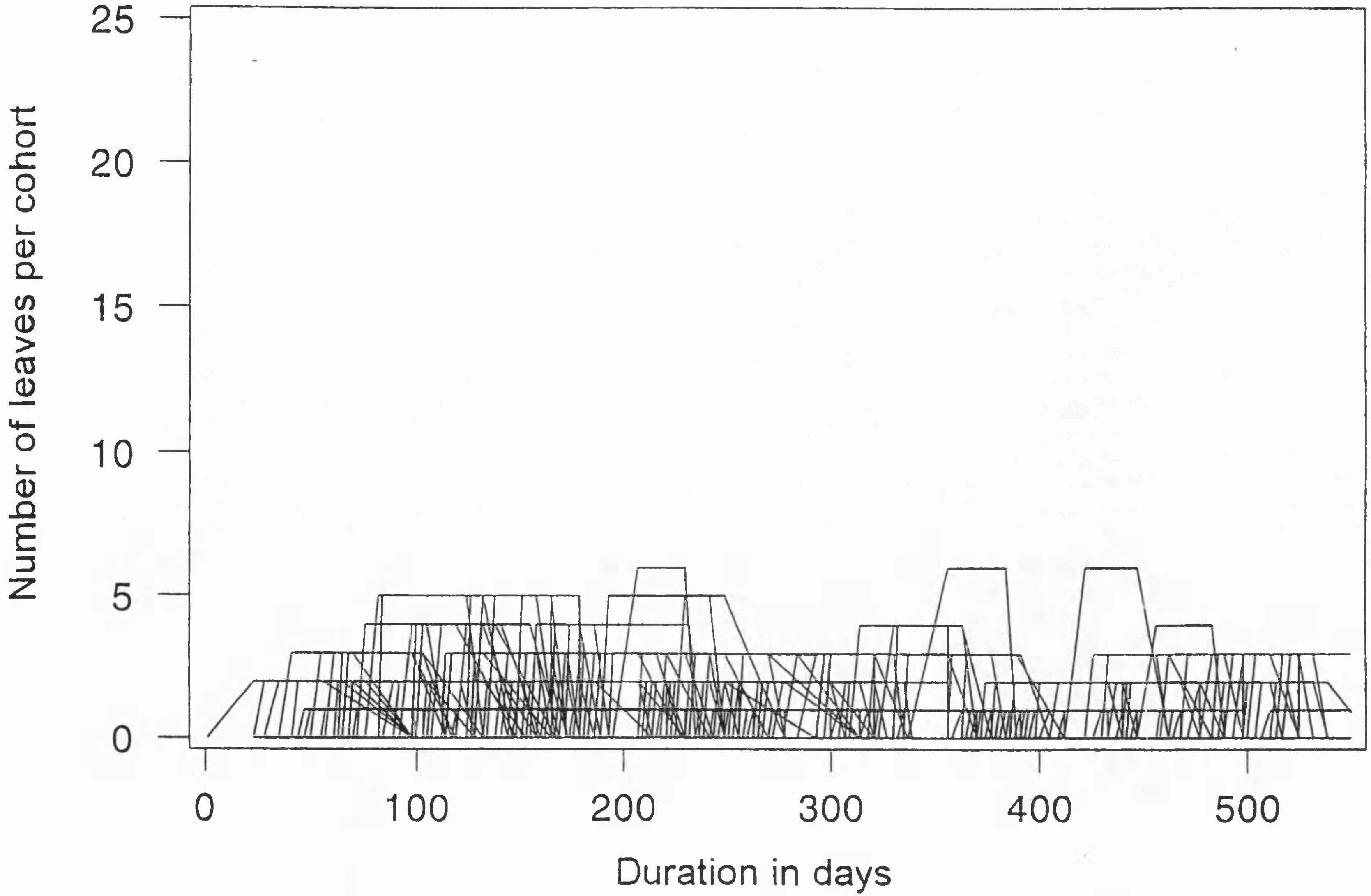
(i) Number of leaves per cohort



(ii) Duration of cohort against number of leaves in cohort

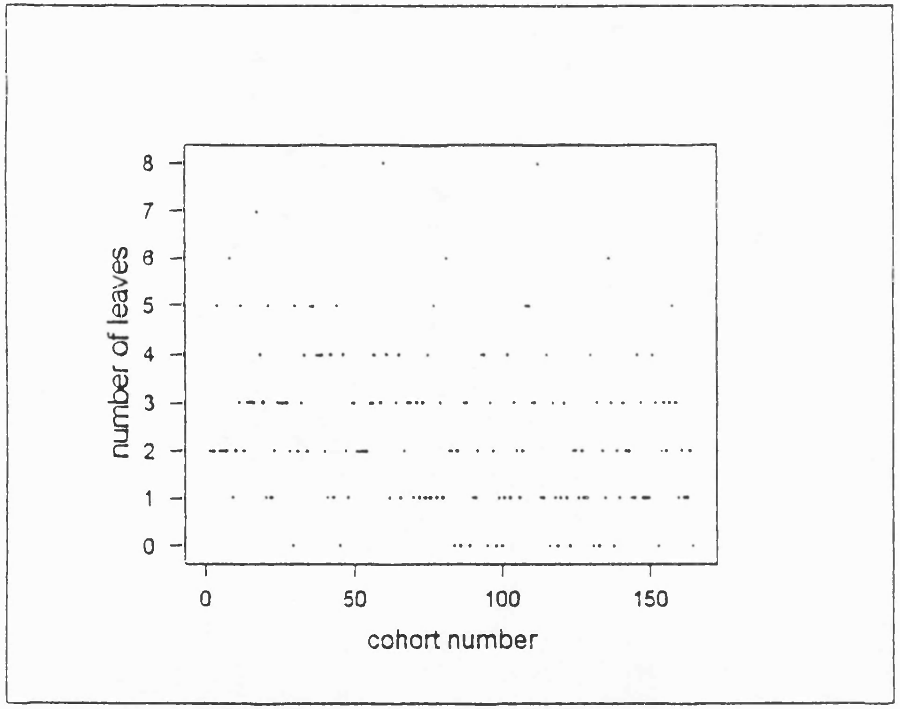


(iii) Life span of cohorts of leaves for S5/33

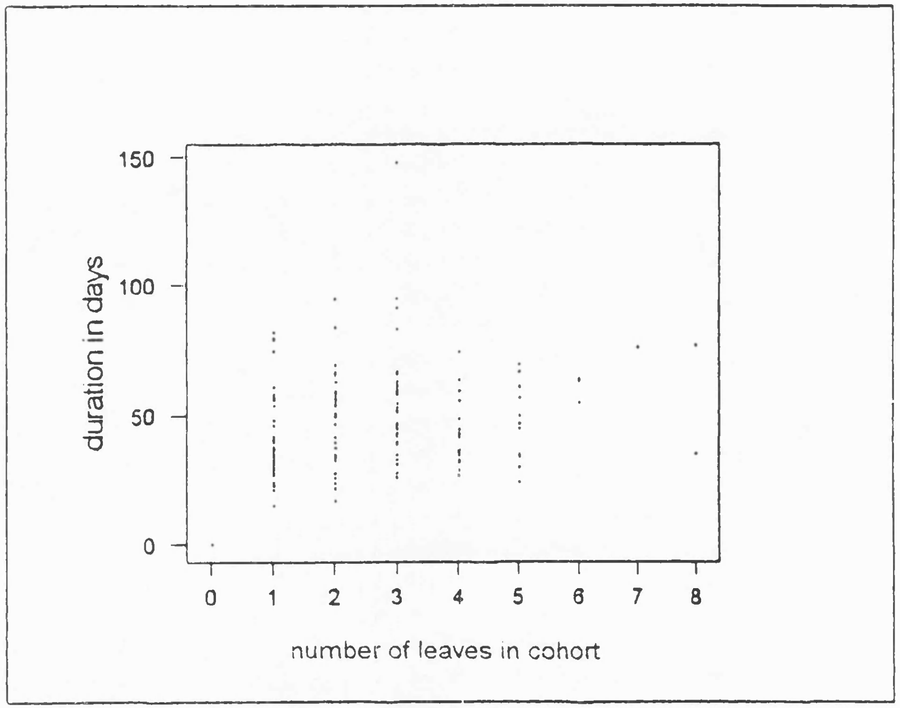


(I) # Results from leaf turnover experiment for S5/43

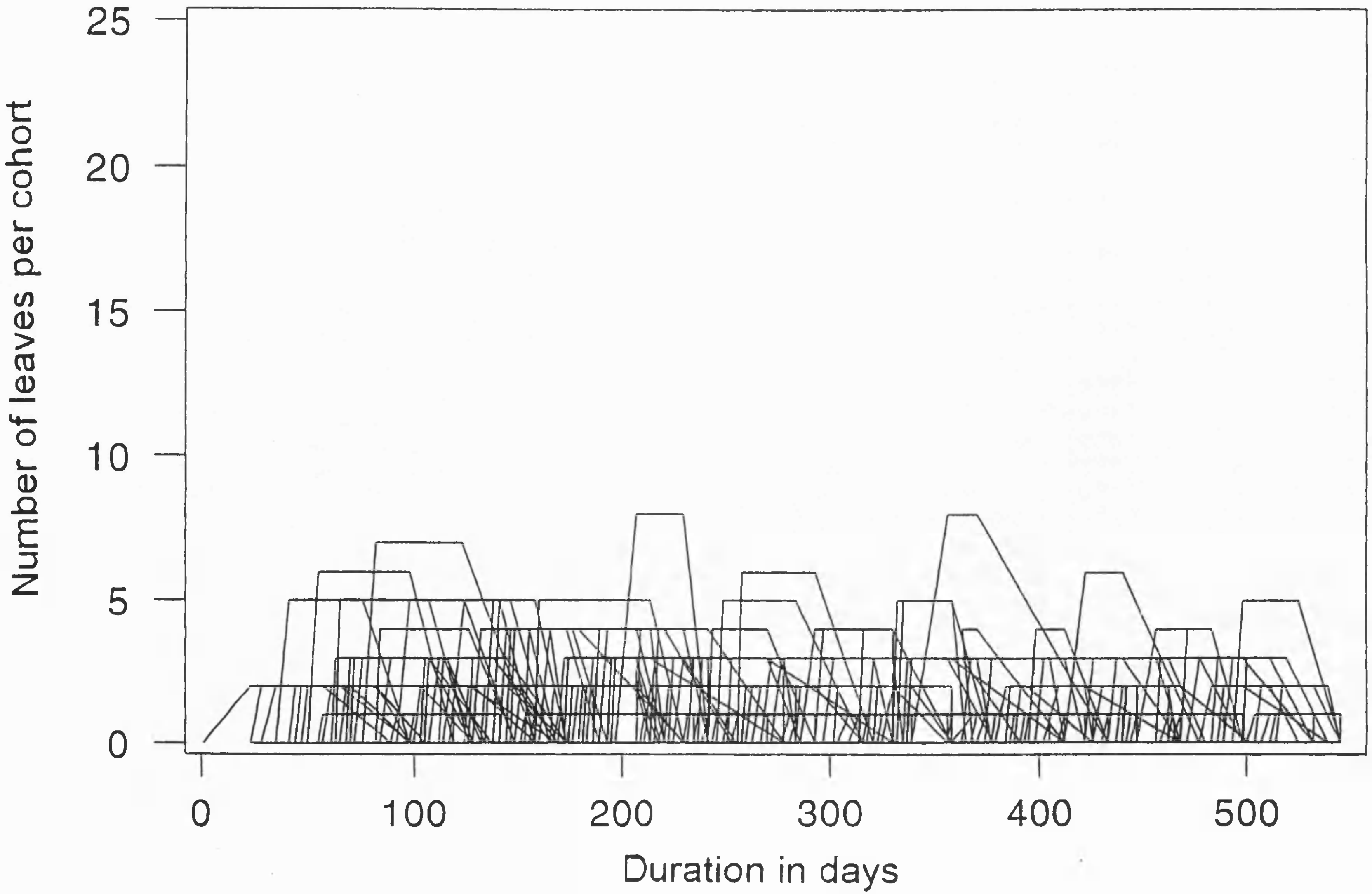
(i) Number of leaves per cohort



(ii) Duration of cohort against number of leaves in cohort

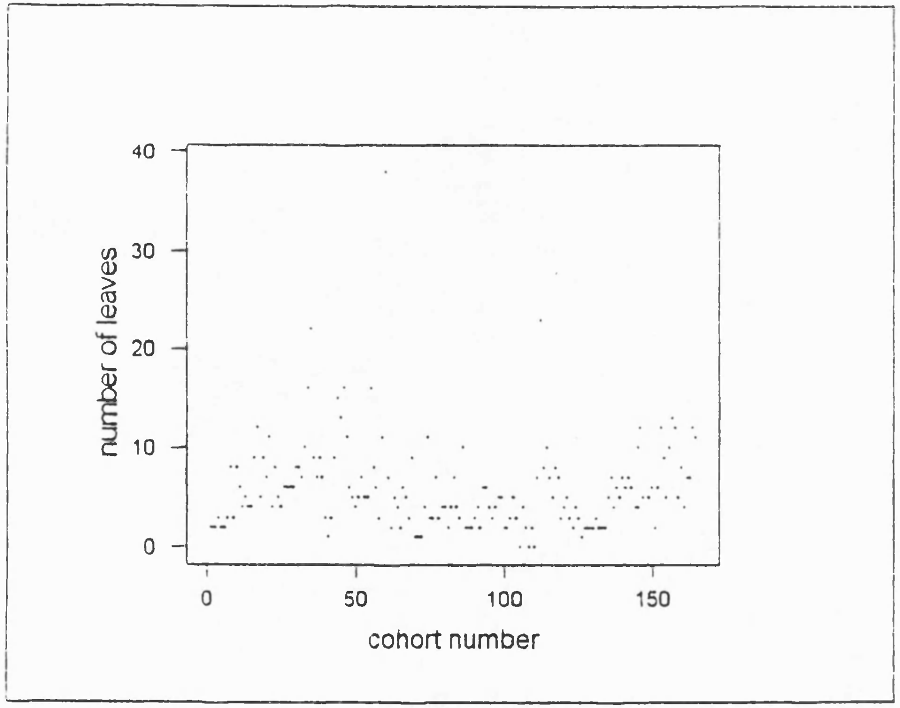


(iii) Life span of cohorts of leaves for S5/43

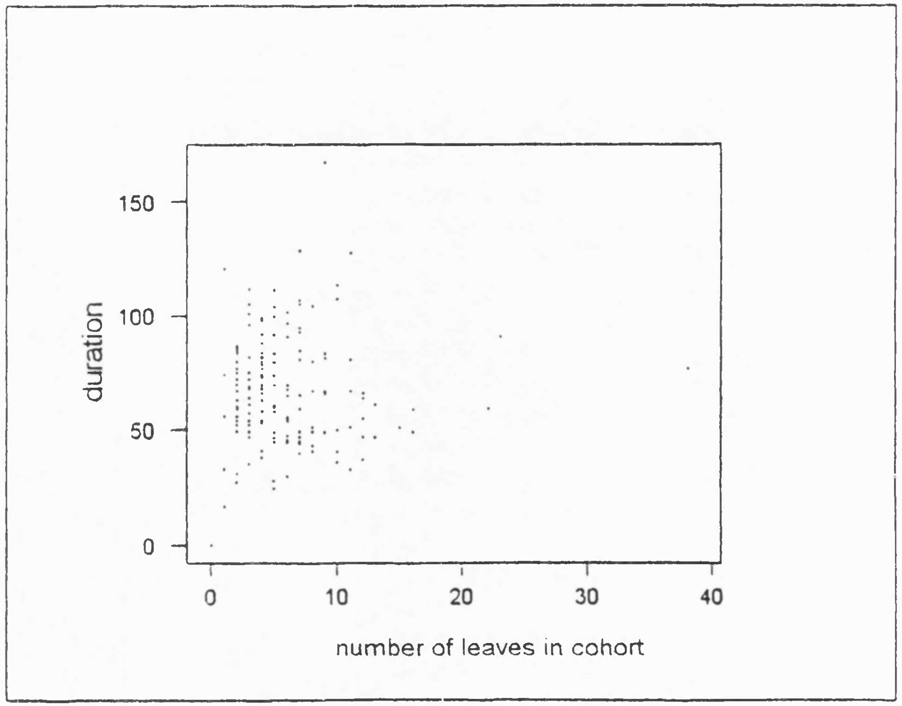


(m) Results from leaf turnover experiment for W2/63

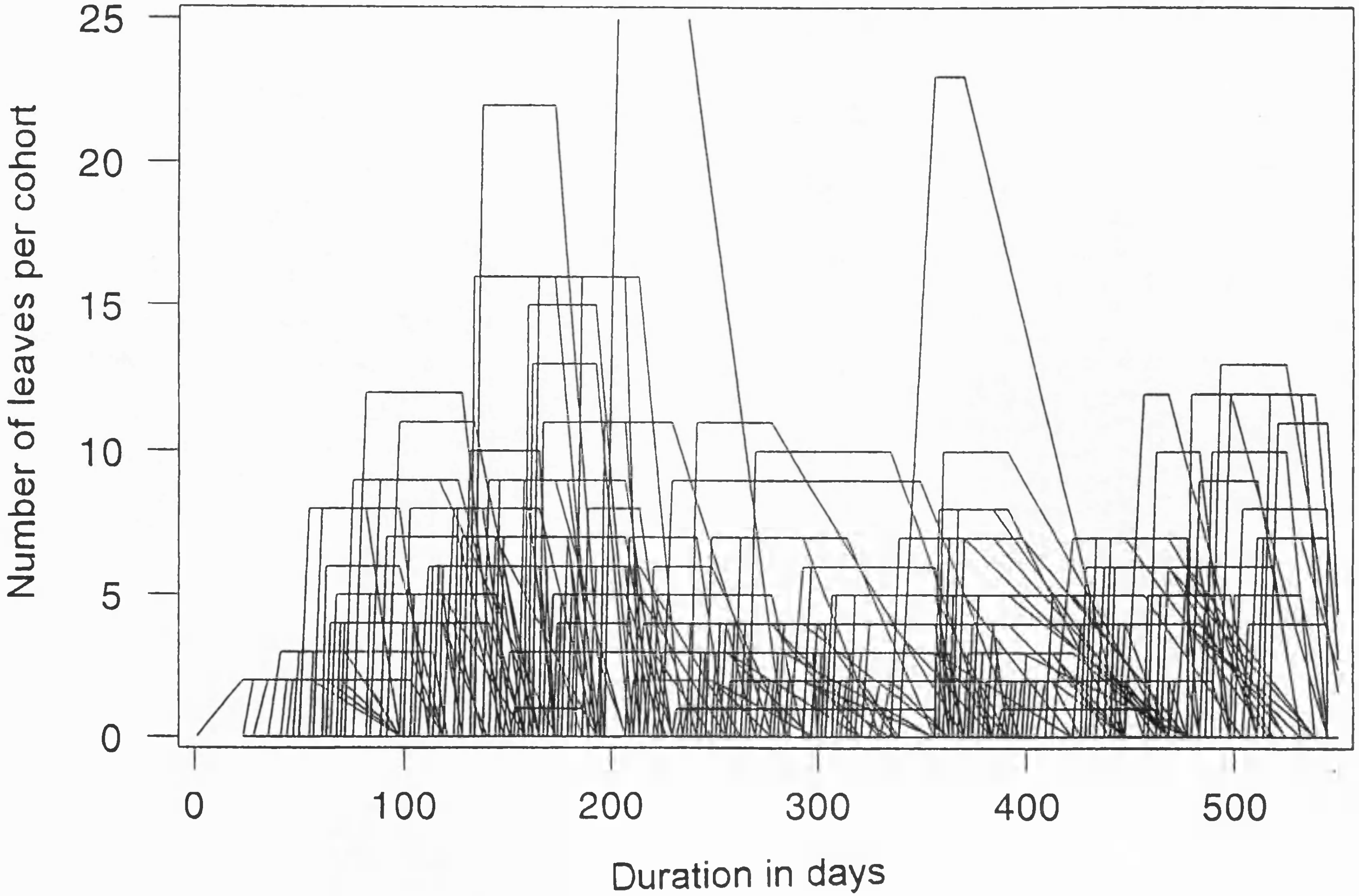
(i) Number of leaves per cohort



(ii) Duration of cohort against number of leaves in cohort

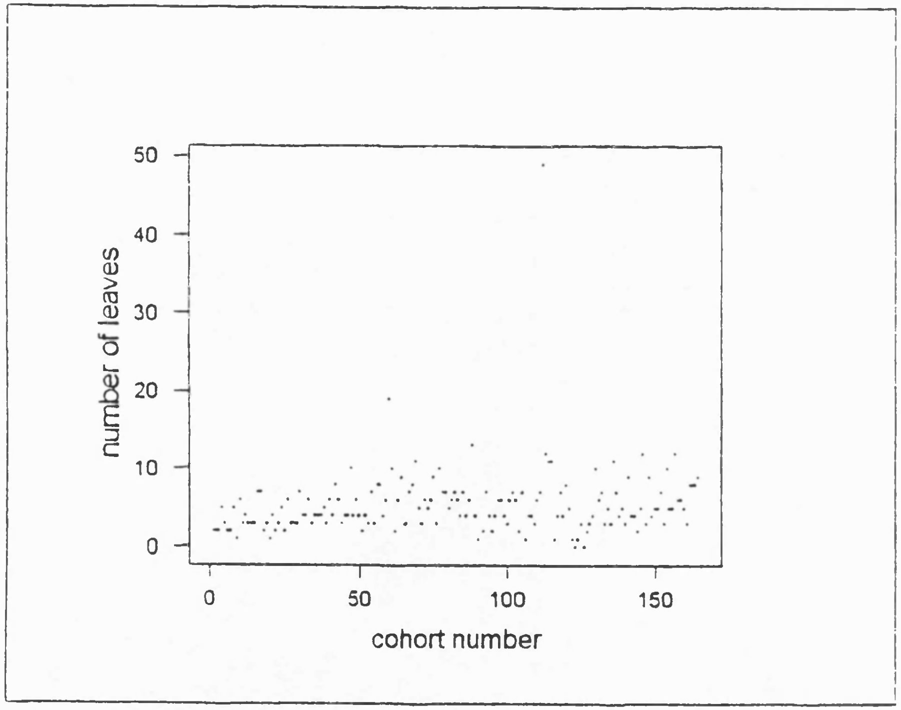


(iii) Life span of cohorts of leaves for W2/63

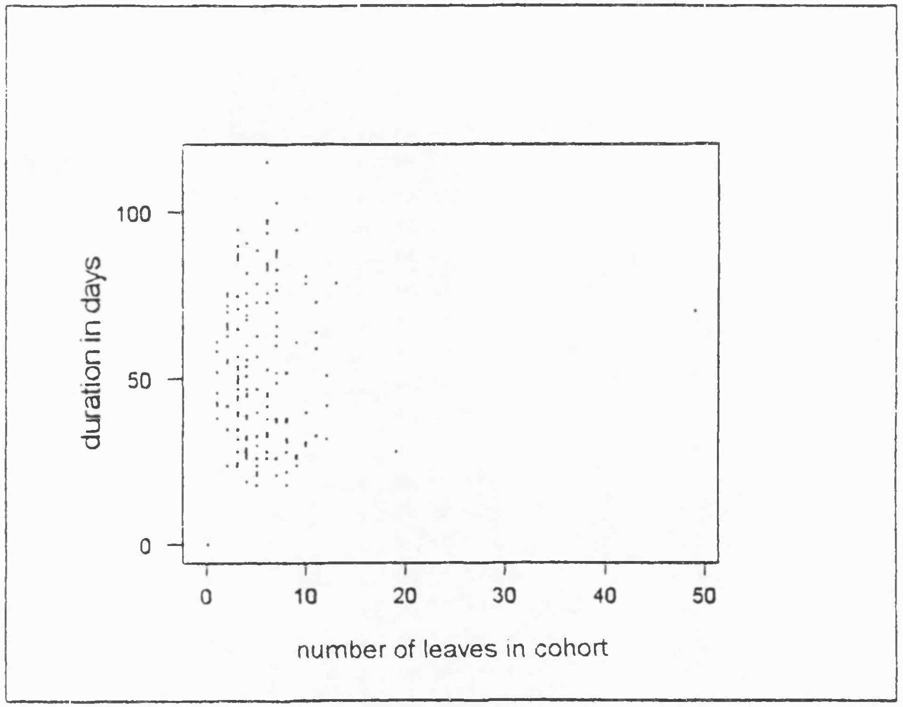


(n) Results from leaf turnover experiment for W2/81

(i) Number of leaves per cohort



(ii) Duration of cohort against number of leaves in cohort



(iii) Life span of cohorts of leaves for W2/81

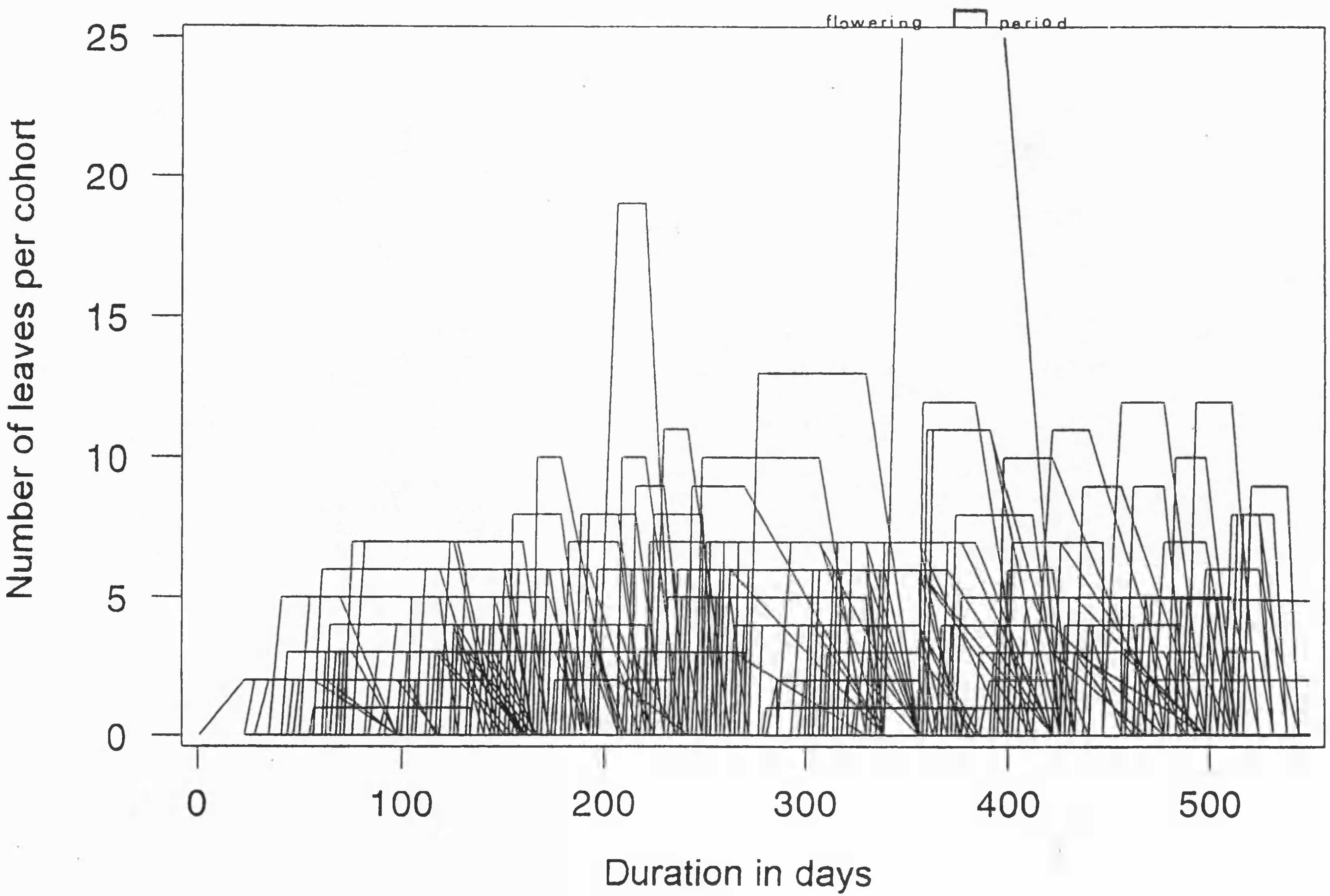
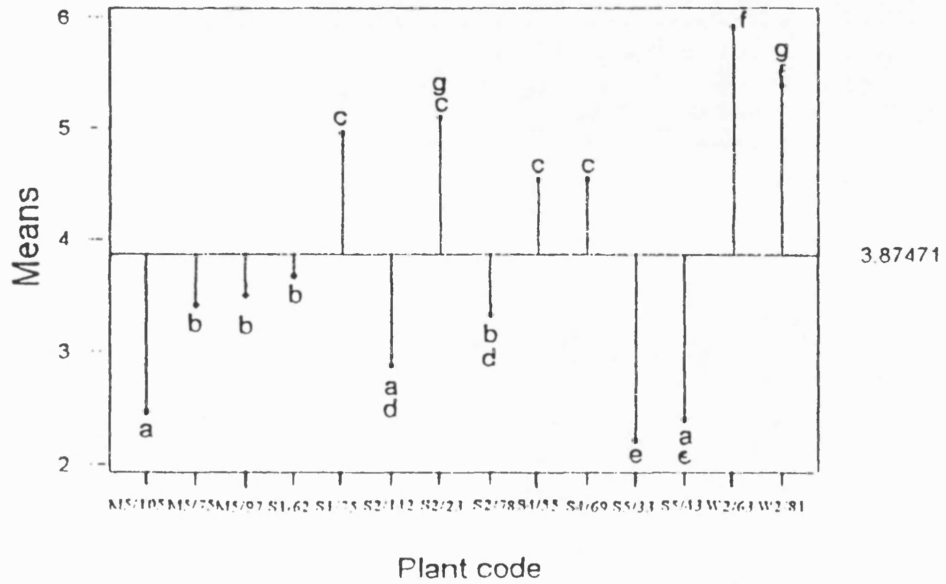


Figure 13

Analysis of means for "leaf turnover" experiment.

Horizontal line represents overall mean.
Means with the same letter are not significantly different. Those with different letters are significant at $p<0.05$.

Analysis of means of leaves per cohort



Analysis of means of duration of cohort

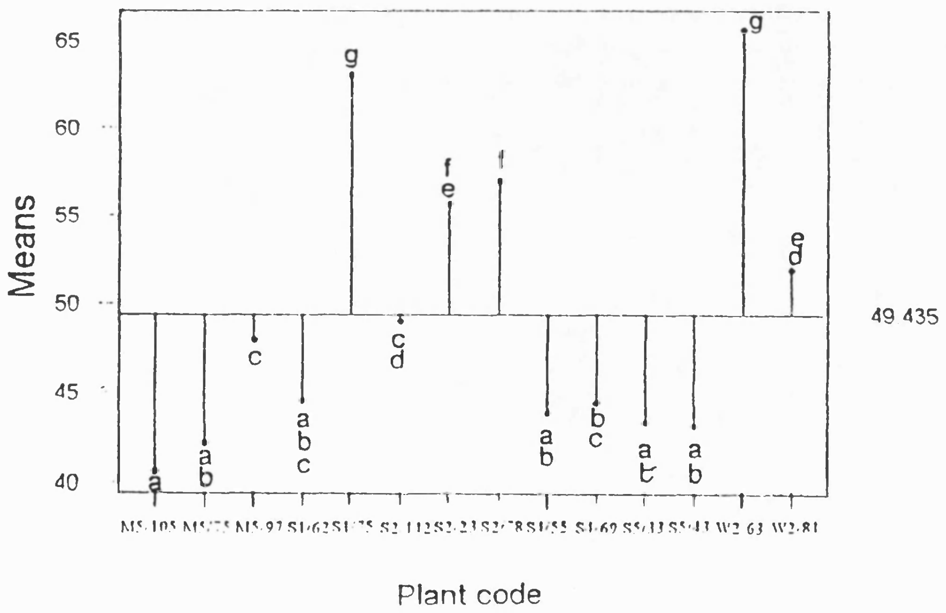
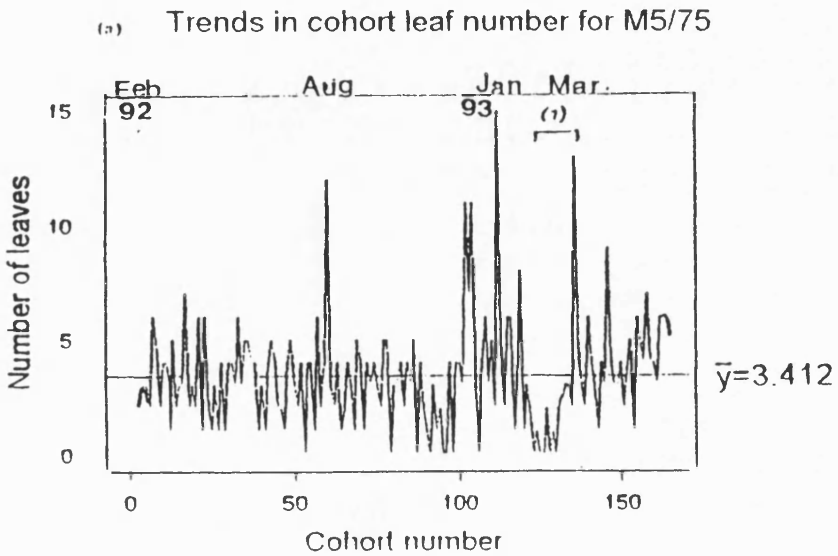
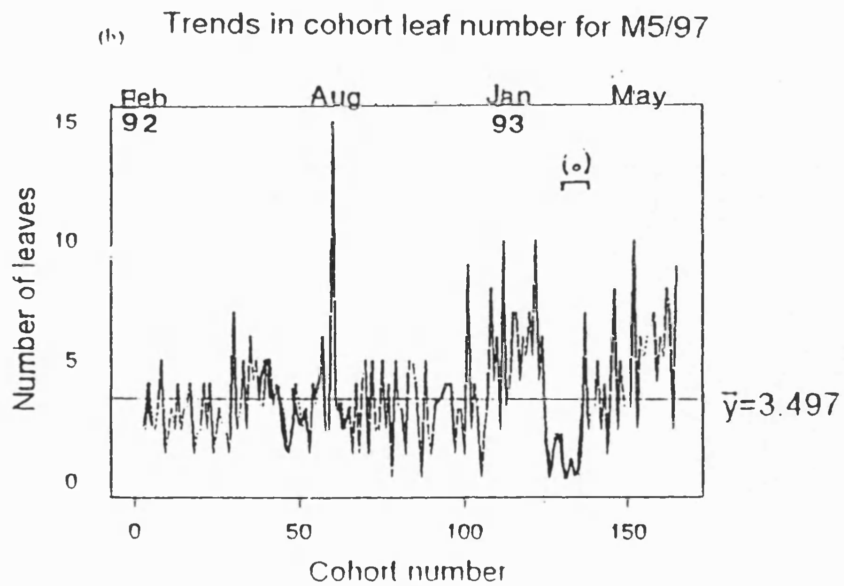


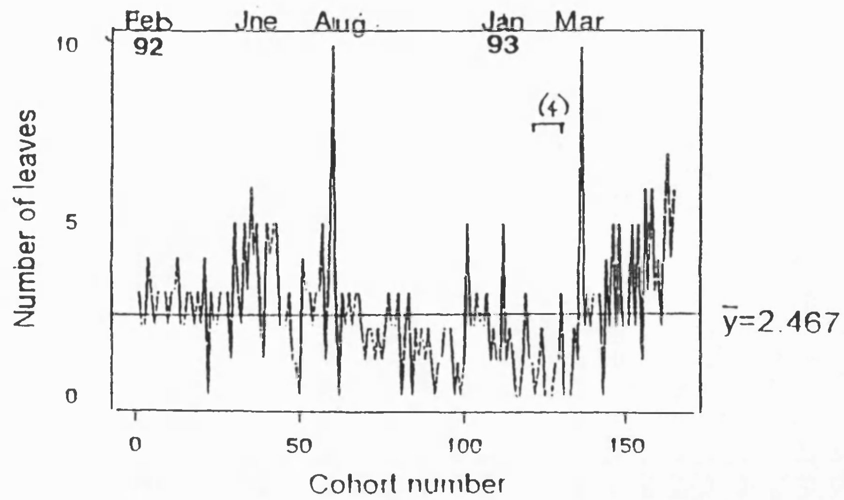
Figure 14

The following graphs show the number of leaves per cohort against cohort number for each plant, with the mean number of leaves shown as a horizontal line. (NB The vertical scales are not identical). The horizontal scale at the top indicates the time span of the experiment in months which is identical for each graph. Square brackets (on six of the graphs) indicate the period over which flowering took place, with the number of capitula produced printed above the brackets.

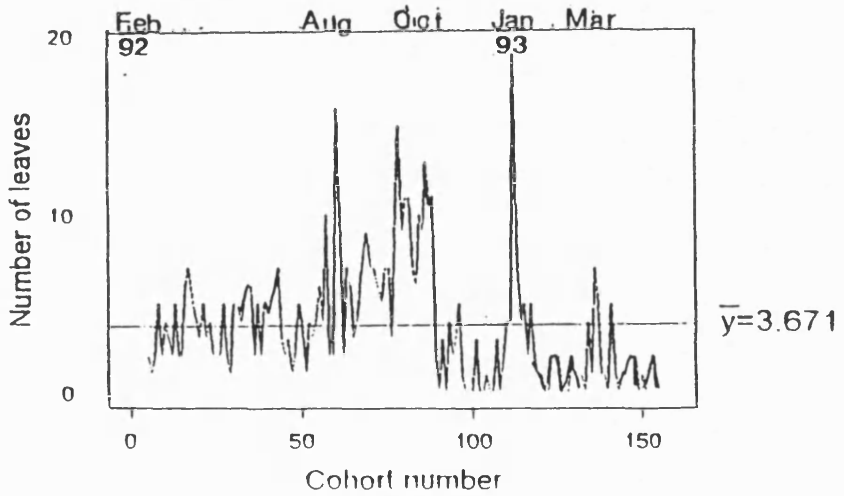




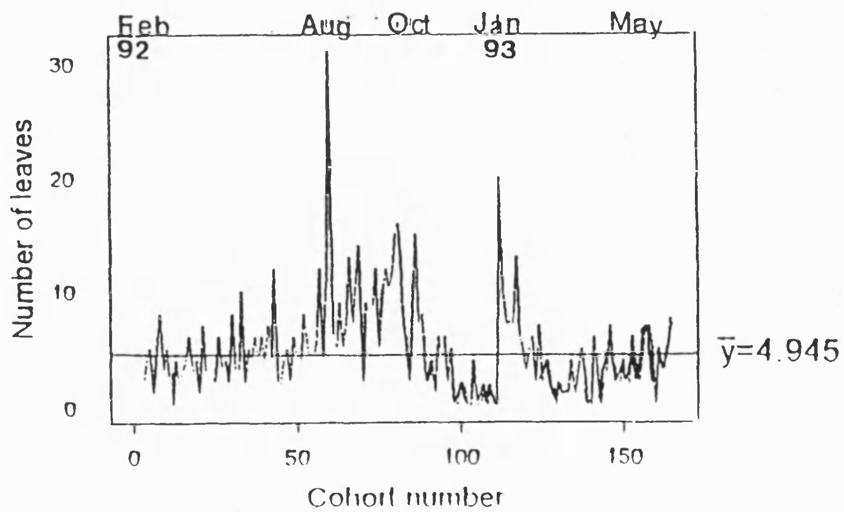
(c) Trends in cohort leaf number for M5/105



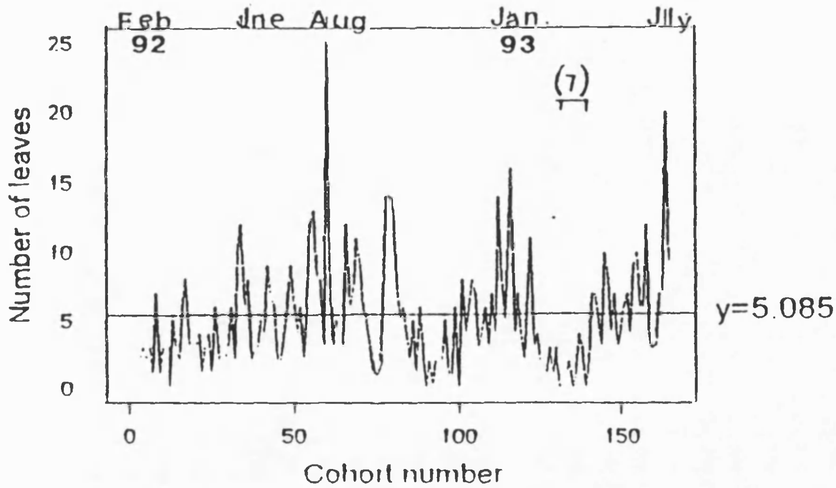
(d) Trends in cohort leaf number for S1/62



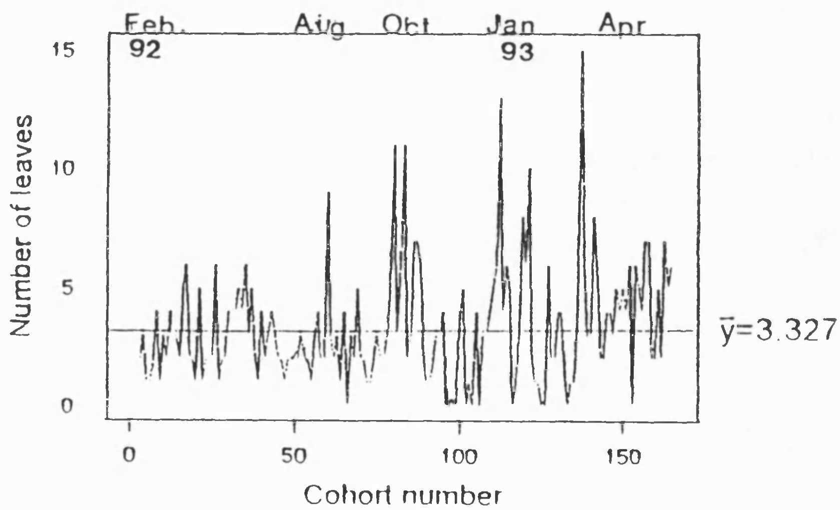
(e) Trends in cohort leaf number for S1/75



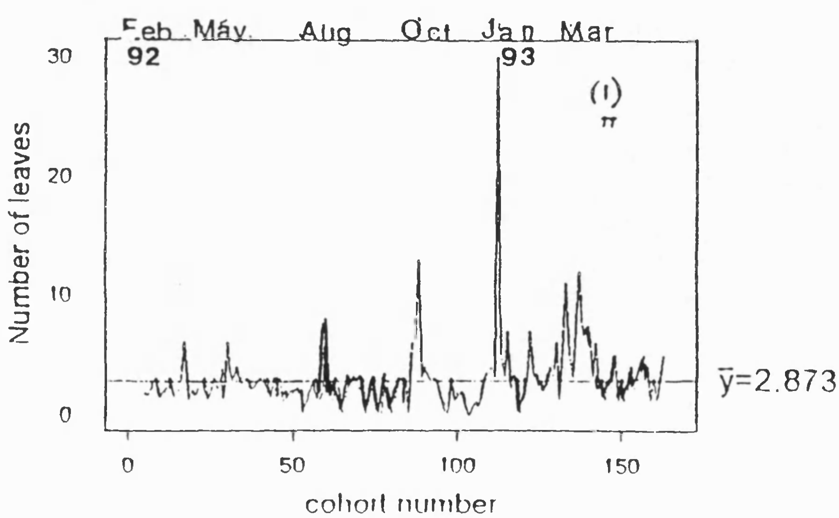
(f) Trends in cohort leaf number for S2/23



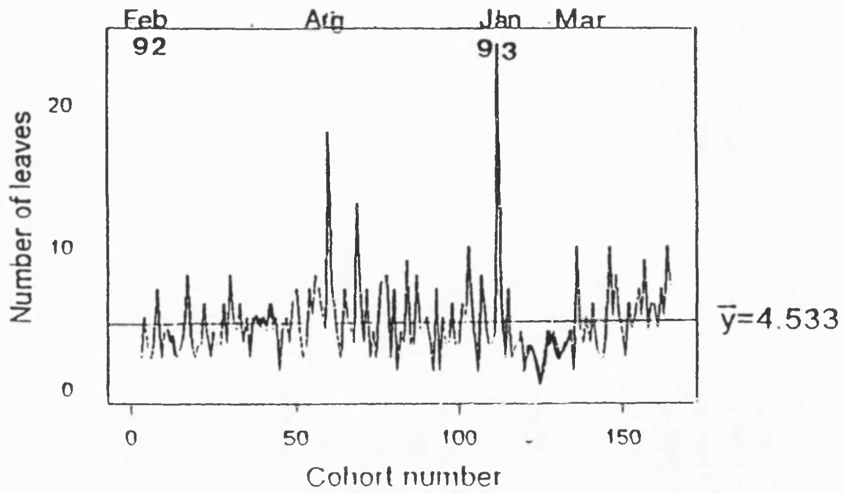
(g) Trends in cohort leaf number for S2/78



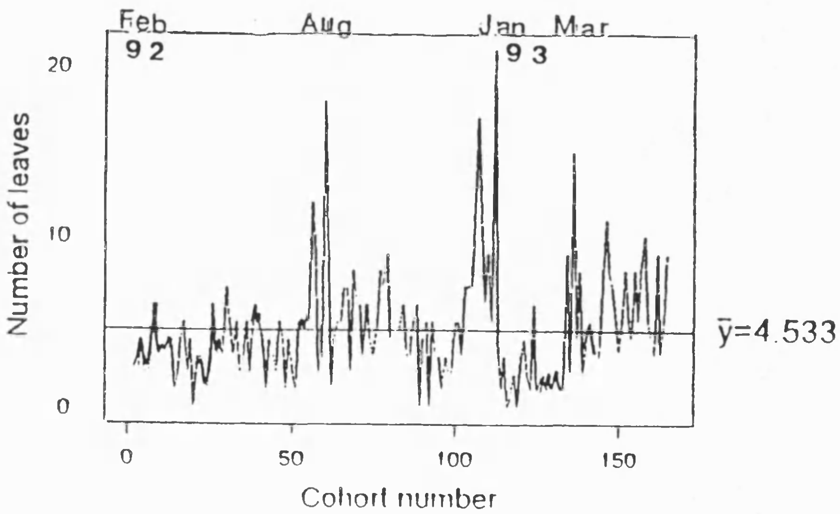
(h) Trends in cohort leaf number for S2/142



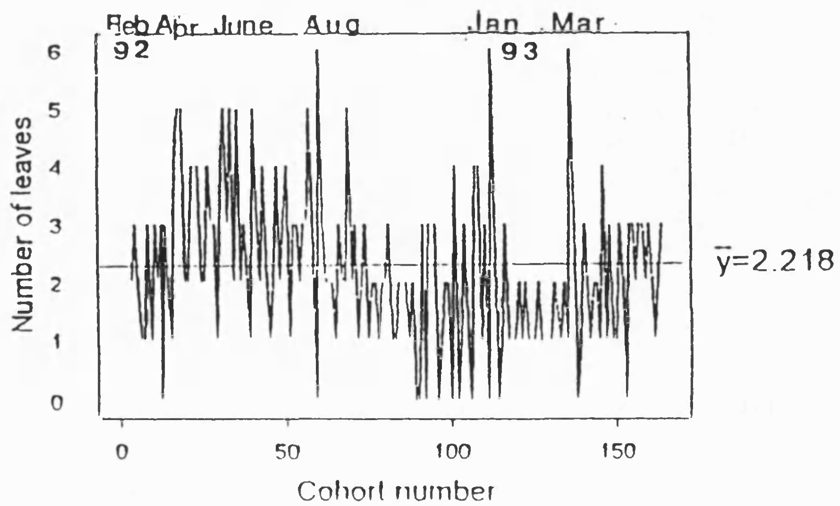
(i) Trends in cohort leaf number for S4/55



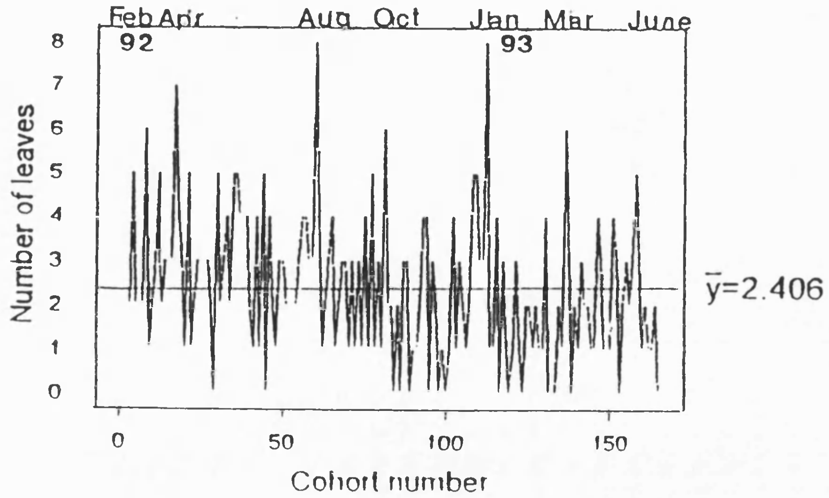
(j) Trends in cohort leaf number for S4/69



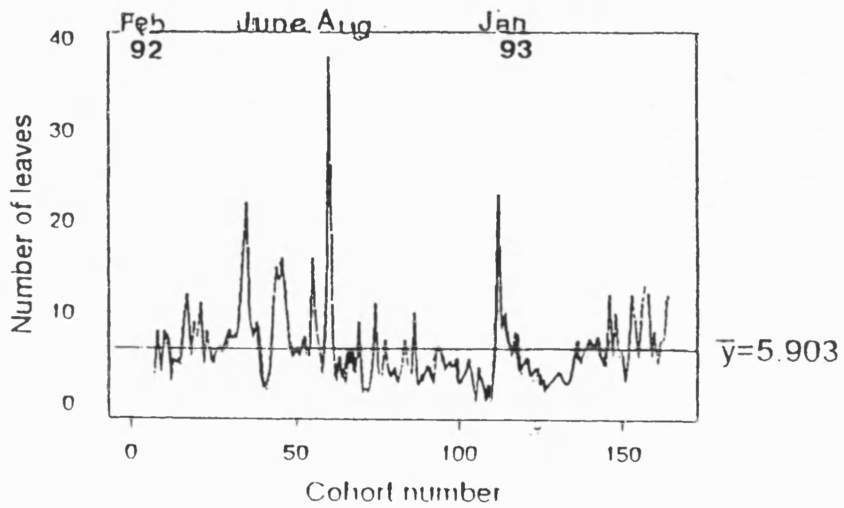
(k) Trends in cohort leaf number for S5/33



(i) Trends in cohort leaf number for S5/43



(iii) Trends in cohort leaf number for W2/63



(ii) Trends in cohort leaf number for W2/81

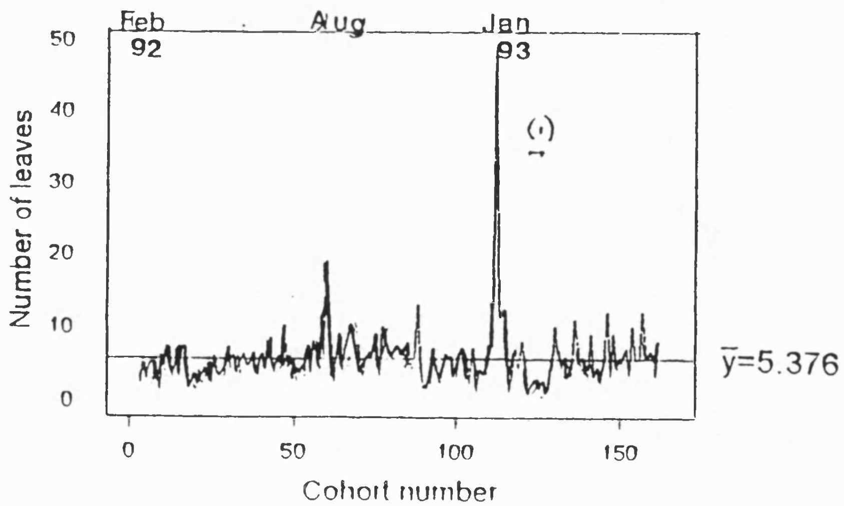


Figure 13 shows the analysis of means of both the number of leaves per cohort and the duration of cohorts. Trend analysis was applied to the size of cohorts in an attempt to identify any underlying patterns which could be used to predict future trends in cohort size. The results of this analysis were unsatisfactory as they gave a high value for absolute percentage error: a high value indicates that the analysis has provided a poor description of the data. Moreover, as some cohorts contained no leaves, only a linear or quadratic expression could be fitted using trend analysis. This further limited the usefulness of this method. Consequently, the results are not reported. A satisfactory alternative to trend analysis is to present the data in the manner shown in Figure 14. (For details see legend). For plants which produced more than one capitulum, regression analyses were performed. These regressions were of: a) the number of achenes produced against position in the flowering sequence b) mean achene weight against flower number and c) mean achene weight against total number of achenes produced for each capitulum. A correlation was also calculated between total achene number and the mean weight of achenes. The results are summarised in Table 23.

Table 22: Summary of flowering characteristics for the 6 plants that flowered.

Mean achene weight calculated by dividing total achene weight by total achene number.

Plant code	No. capitula produced	Total number achenes/capitulum	No empty achenes/capitulum	Mean achene weight (mg) (Wt range not available)
S2/23	7	156	9	0.7282
		260	9	0.5862
		146	4	0.5562
		137	4	0.5788
		77	1	0.7896
		132	3	0.6242
		108	0	0.6574
S2/142	1	199	99	0.1995
W2/81	1	122	2	0.782
M5/75	7	210	6	0.3224
		156	2	0.6686
		152	0	0.5592
		111	5	0.4405
		149	0	0.4597
		161	3	0.4416
		122	0	0.5098
M5/97	6	172	2	0.6529
		179	4	0.624
		123	0	0.4374
		142	1	0.4796
		144	7	0.4111
		155	2	0.4535
M5/105	4	253	2	0.7581
		189	2	0.5709
		229	0	0.4463
		231	2	0.4658

Table 23

Equations relating total achenes produced per capitulum, the mean weight of achenes per capitulum and the position in the flowering sequence for plants that produced more than one capitulum. The following abbreviations have been used: a = total number of achenes produced, w = mean weight of achenes in mg per capitulum and c = capitulum number in sequence.

Plant code	Equation	r^2	p	Correlation
S2/23	a=202-15.3c	36.9%	0.148	
	w=0.632+0.0035c	0.8%	0.852	-0.54
	w=0.766-0.000854a	29.2%	0.211	
M5/75	a=184-8.61c	36.3%	0.152	
	w=0.455+0.0003c	0.0%	0.99	-0.346
	w=0.667-0.0012a	11.9%	0.448	
M5/97	a=168-5.17c	23.2%	0.333	
	w=0.666-0.0452c	66.2%	0.049	0.894
	w=-0.186+0.00463a	79.9%	0.016	
M5/105	a=230-2.4c	1.3%	0.884	
	w=0.811-0.1c	82.0%	0.094	0.341
	w=0.153+0.00182a	11.6%	0.659	

Discussion

There was no clear pattern of leaf 'birth' evident from the results of these experiments. (Note: All plants except for W2/81 had at least 1 interval of 3 days in which no new leaves were produced.) Figure 12(ii) shows that there is no absolute relationship between cohort size and duration, with cohorts of 1-4 leaves lasting from 25 days to almost 100 days. Cohorts greater than 5 leaves tend to last for a shorter period. This is true for all plants.

The analysis of means of number of leaves per cohort (see Figure 13) shows that

S5/33, S5/43 and M5/105 have the lowest means and that W2/63 has the highest mean. Again, there is no overall pattern in the mean number of leaves per cohort. There is some overlap in cohort size.

Changes in photoperiod can bring about a change in development which includes a change in the birth rate of leaves (Ford 1982). This effect is not expected to occur in this experiment as the plants were greenhouse grown in controlled conditions. There are however, differences between clones. The most likely explanation for these differences is that they are due to genetic differences. This conclusion has previously been made for *Taraxacum* by Ford (1982).

Cohort size differences are found within a clone. For example, M5/105 is significantly different ($p<0.01$) from both M5/75 and M5/97. Similarly, S2/23 is significantly different ($p<0.01$) from both S2/142 and S2/78, and S1/62 and S1/75 are significantly different ($p<0.01$) from each other. There is no obvious explanation for these intraclonal differences.

The analysis of means for the duration of cohorts shows a greater overlap between clones than the analysis for cohort size. However there are significant within clone differences. For example, the duration of cohorts of W2/61 and W2/81 are significantly different at $p<0.001$. This is interesting because there is no significant difference between the size of cohorts for these plants. The same can be said for M5/97 and the other two plants from that clone, particularly between M5/75 and M5/97, where no significant difference is detected between the size of cohorts but a significant difference is detected for cohort duration at $p<0.05$. S1/62 and S1/75 are significantly different in both size ($p<0.01$) and duration ($p<0.05$). For plants from the S2 clone, S2/142 is significantly different ($p<0.05$) for duration from both S2/23 and S2/78. Again there is no obvious explanation for these within clone differences. For example, they do not correspond to parent plant achene weights as can be seen from Table 21.

Note that only three of the six clones in the experiment flowered, with M5 being the only clone in which all plants flowered. S2/142 produced one capitulum which contained almost 50% empty achenes, although this capitulum and flower had been damaged by mice. The data in Table 22 are presented in order of flowers being produced, which will be referred to as the 'flowering sequence'. As this sequence is limited, and because the results are inconclusive, a more detailed description of flowering sequence will be given in the next chapter. But from the regression analyses (Table 23), it appears that achene number is influenced by the position of the capitulum in the flowering sequence in two plants, (S2/23 and M5/75), where a negative correlation is found between the variables, indicating that for these plants fewer achenes are produced in later capitula than in earlier capitula. This pattern is not found in the other two M5 plants, where a positive correlation (a high correlation in the case of M5/97) is found. The probabilities of mean achene weight being correlated with position in the flowering sequence, and of mean achene weight being correlated with achene number are both $p<0.05$ for M5/97 . Although M5/105 also shows a positive correlation between achene number and mean weight there are no significant factors shown in the regression equations.

Figure 14 shows a fluctuation in the number of leaves produced by consecutive cohorts. A cohort with a higher number of leaves was invariably followed by a cohort containing fewer leaves. A further pattern on a longer time scale is overlaid on this. Each graph displays a series of peaks and troughs. The ones occurring in August and January were following a holiday period and the Christmas closure of the university. It was decided to include these large cohorts so these periods could be identified. One way of trying to understand the pattern produced is to focus on periods during which fewer leaves are produced. These show on the graphs as 'dips'(ie where the number of new leaves falls below the mean value). These can be clearly seen in M5/105, S1/62 and both S5 plants. All plants display such a dip at around cohort 125 (beginning of February 1993), and in those plants that flowered it may be seen that this cohort precedes the flowering period. A reasonable interpretation of this dip could be that there is direct competition between the leaves and the capitula growing from the buds that had developed at the base of the rosette. It was found at this stage that photosynthetic area was reduced and that this reduction was achieved by plants producing fewer leaves (not by them producing smaller leaves). Clearly, competition between leaves and capitula buds cannot be the explanation for the dip at around cohort 125. Nor can it explain the dips observed in non-flowering plants at other times. Some dips occur at the end of the year. These may be due to the end of the growing season, and may be an indication of the periodicity which is known to occur in the field. Finally, some dips may be due to resources being channelled into root growth. The design of this experiment did not allow for root weight to be assessed. However, in the root/shoot allocation experiment reported earlier in this chapter, both clones (M2 and W3) exhibited a change in allocation to roots and shoots, with more resources being channelled into shoot growth at around 21 days. From then on, the roots have a greater increase in fresh weight than the shoots. This earlier experiment looked at early stages of seedling growth, but there is no reason to suppose that this movement of resources does not continue throughout the life of the plant.

One method of obtaining an estimation of the time interval of the dips is to measure the horizontal distance between the start and end of the dip. In all graphs except S2/78, the longest dip is from the end of January to March, the period before natural onset of flowering. S5/33 shows this particularly well. S1/78 has the longest dip at the end of the year (November-December) followed by a smaller one in February. As this experiment lasted for over 500 days, it is interesting to compare periods one year apart (e.g. March 1992 with March 1993). In the M5, S2, S4 and W2 plants, cohorts were larger for the one year old plants and showed a gradual increase in size from that period to the end of the experiment. This is not evident in S1 plants. S1/62 did not display an increase in size, whereas a small increase was evident for S1/75. The two S5 plants, however, did not show any increase in size at one year. In plants that are one year old, the tap root may be sufficiently established to be able to act as a reservoir during periods of reduced photosynthetic activity or during periods of stress.

The rate of leaf production in *Xanthium* was found to be reduced by the floral initiation hormone ecdysterone (Jacobs and Suthers 1971). Similar results were found by Bazzaz and Harper (1977) in *Linum usitatissimum,* where the rate of leaf death was clearly related to the number of seeds ripened; the authors suggest that the developing seeds were acting as a sink for nutrients, perhaps forcing the withdrawal of nutrients from the leaves and hastening their death. This pattern is not found in *Taraxacum*. However, *L. usitatissimum* is an annual which dies after setting seed. Bazzaz and Harper also found that phases of leaf birth and death scarcely overlap in this species although they do acknowledge that the two phases can occur together over long periods in other species. In *Taraxacum,* leaf birth and death continually overlap. This may be due in part to the plant growing as a rosette, and in part to it being a perennial which needs to maintain some growth, however slow, during certain periods of the year (e.g. winter). Although field-grown *Taraxacum* can exhibit a decrease in the size of the rosette during the winter, this was not detected in the greenhouse. At low light levels, leaves of *L. usitatissimum* died at a slower rate than those in full light (Bazzaz and Harper 1977) and it is possible that the reduced rates of leaf death observed during the winter months (Williamson 1976; Ford 1981) in *Taraxacum* are the result of temperature and light effects.

Bazzaz and Harper (1977) noted that when death occurred in a population of leaves it swept as a continuing process up the plant, with the result that it was rare for any leaf to die out of sequence. The same may be true for *Taraxacum,* where there is a continual production of new leaves from the centre of the rosette which compensates for the death of leaves (the oldest) on the periphery. There was a little overlap and some leaves did die 'out of order' before the previous cohorts were completely dead. It may be concluded that a leaf's position within the rosette determines its onset of death. The nearer the leaf is to the periphery, the higher its probability of onset of death. Other authors quote a positional effect for leaf longevity, with longevity being greater for leaves higher on the stem in both annuals and perennials (Ford 1982).

Chapter 5

In this chapter an investigation into achene production is described. In particular, it examines the relationship between flower number (i.e. position of the capitulum in the flowering sequence), total achene number per capitulum, total achene weight per capitulum, and the number of viable achenes and the mean achene weight, again per capitulum. The relationships between these factors and the weight of the achene from which the study plant was produced are also described.

5.1 Introduction

In reviewing patterns of change of seed weight, Cavers and Steel (1984) noted that, within a species, seed weight differences occur between plant populations separated spatially and temporally. Studies with several species have also shown that seed weight within a population tends to decline during a season (Rorison 1973; Turner *et al.* 1979; O'Toole 1982). For example, investigations of *Amaranthus retroflexus* L. and *A. powellii* Wats. have recorded a marked decline in weight from early to late maturing seeds (McWilliams *et al.* 1968; Frost 1971; Schrimpf 1977).

According to McGinley (1988), changes in seed weight with time are thought to be the result of both developmental constraints and selection for variable investment. In his work with *Tragopogon dubious,* he concludes that as mean seed mass per head is positively correlated with total seed mass per head and the latter quantity declines over the season, this decrease may be influenced by seasonal changes in the size of the resource pool, particularly by changes in the maternal resource pool invested in offspring. However, this alone cannot explain the observed pattern of variation, as seed mass variation is not only seen in natural populations. For example, Primark and Antonovics (1981) have shown that variation for seed mass is found in *Plantago lanceolata* grown under controlled conditions. In *Desmodium paniculatum,* differences in seed size are found between field-grown and controlled environment-grown plants (Wulff 1986). These differences are thought to be due, at least in part, to the conditions to which the mother plant is exposed. Variation in seed size also has both genetic and plastic components (Marshall 1986). By using an apomict, such as *Taraxacum*, it is possible to minimise variation due to the genetic component.

5.2 Materials and Methods

Achenes of a known weight, obtained from each of the 15 clones of original material, were sown in individually labelled compartments of seed trays in Levington Universal F2 compost (see chapter 2). When large enough to handle (i.e. cotyledons fully emerged and 2 true leaves present), selected seedlings were transferred to 6 inch pots containing Levington Universal M2 compost. Seedlings were selected to represent the range of achene weights exhibited by each clone. For clones with very poor germination (see chapter 2) the choice of seedlings was restricted, as seedlings were needed both for this experiment and for the 'leaf turnover' experiment discussed in the previous chapter (chapter 4).

The pots were randomly arranged, using random number tables, on gravel on the floor of the greenhouse which was kept frost free. (There was no particular temperature control except that it was kept above 1^0C). Supplementary lighting to give a 12h day during the winter months (November - February inclusive) was provided. The seedlings were placed in the greenhouse at the beginning of February 1992. The ages of plants (in days) were calculated using 15th January 1992 as day zero.

The date each flower opened was recorded. A flower was recorded as opening when yellow florets could first be seen emerging from the bud. All achenes from each capitulum were collected by tying a paper bag over the flower and allowing the achenes to ripen fully before removal from the parent plant. Each bag was identified with a plant code, flower number and the date of flower opening.

After collection, the achenes were cleaned and the pappus was removed. The total number of achenes, the number of empty achenes,and the total weight and mean weight of achenes for each capitulum were recorded. The mean weight was calculated by dividing total weight by total number. Consequently, information on weight range is not available. (Because of the large number of achenes, it was not possible to weigh each achene individually).

In total, 86 plants from 14 of the original 15 clones were monitored in this way. The plants were monitored for over 500 days, from January 1992 until June 1993.

5.3 Results

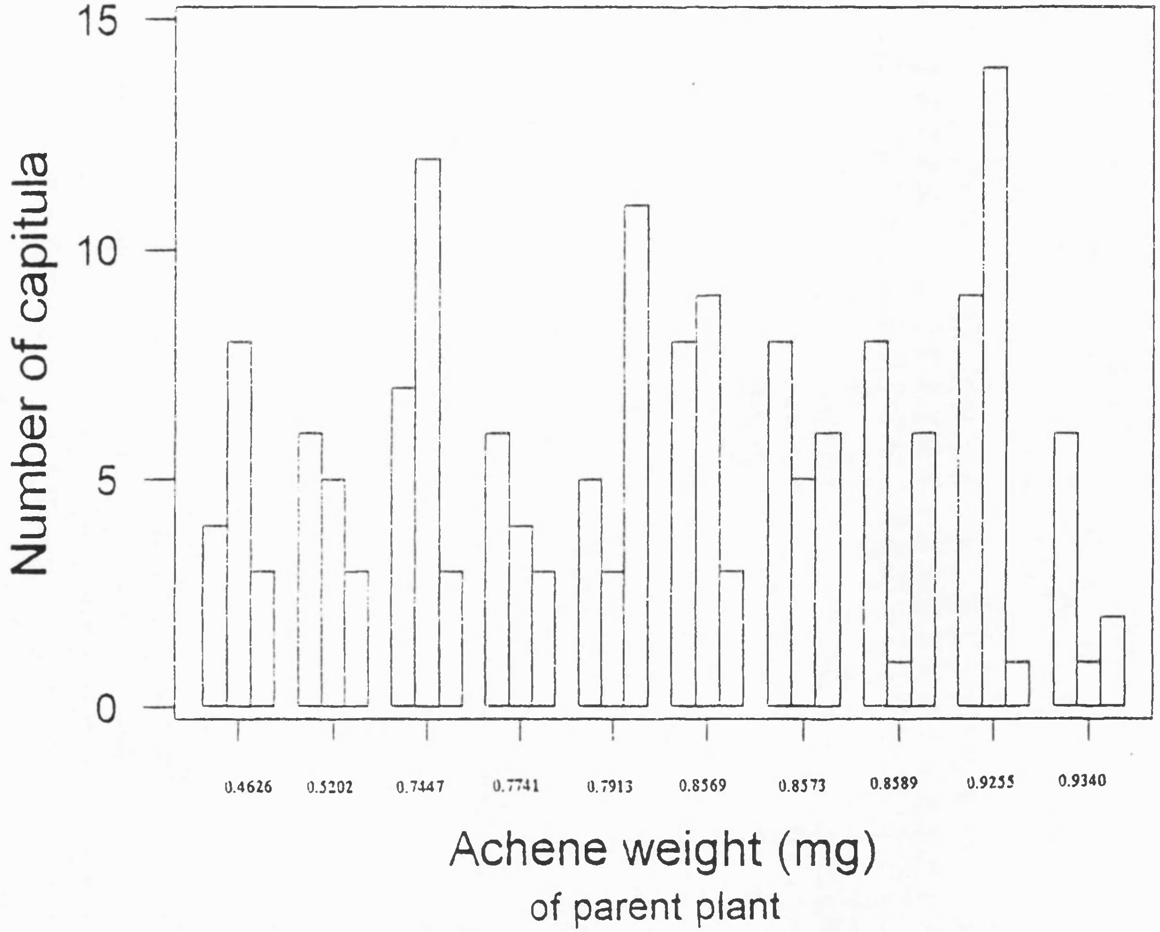
Flowering of the plants occurred during 3 separate time intervals. The first flowering period was in May 1992, when plants were about 120-130 days old. The second occurred in late August 1992, when plants were about 190 days old. The third occurred between December 1992 and April 1993 when plants were over 350 days old.

Clones W1, W3, W5 and M2 produced capitula in all 3 periods. All plants from these clones flowered during the first period and again during the second period, but not all of these plants flowered during the third period. All other plants (from all other clones) flowered in only one period, most usually at around 190-200 days, although some did not flower until the spring of the second season.

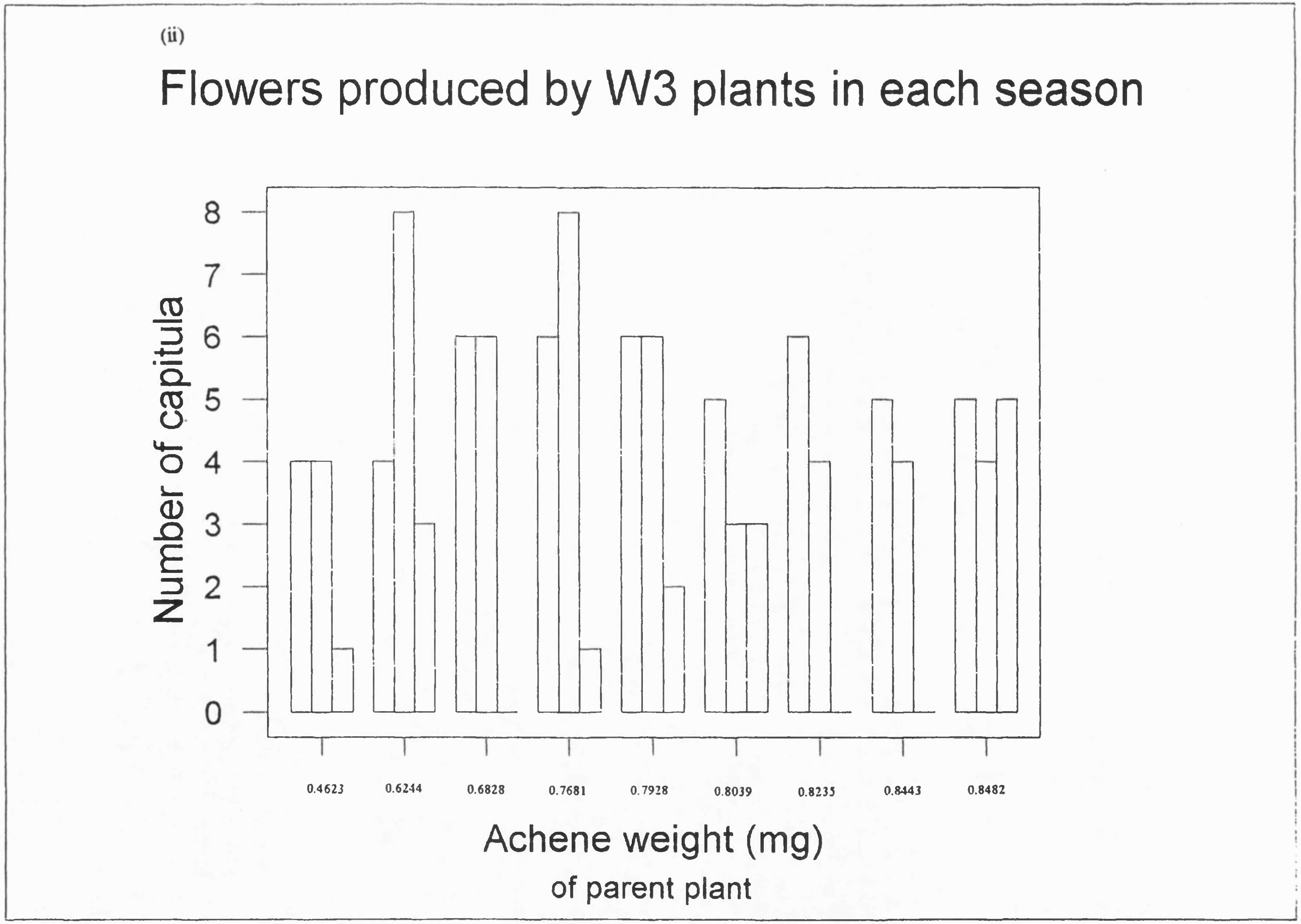
Figure 15 (i)-(iv) shows the number of capitula produced in each flowering period for the 4 clones that flowered more than once. The achene weight of the parent plant is given along the x-axis in ascending order. It can be seen that there is no consistent pattern in the number

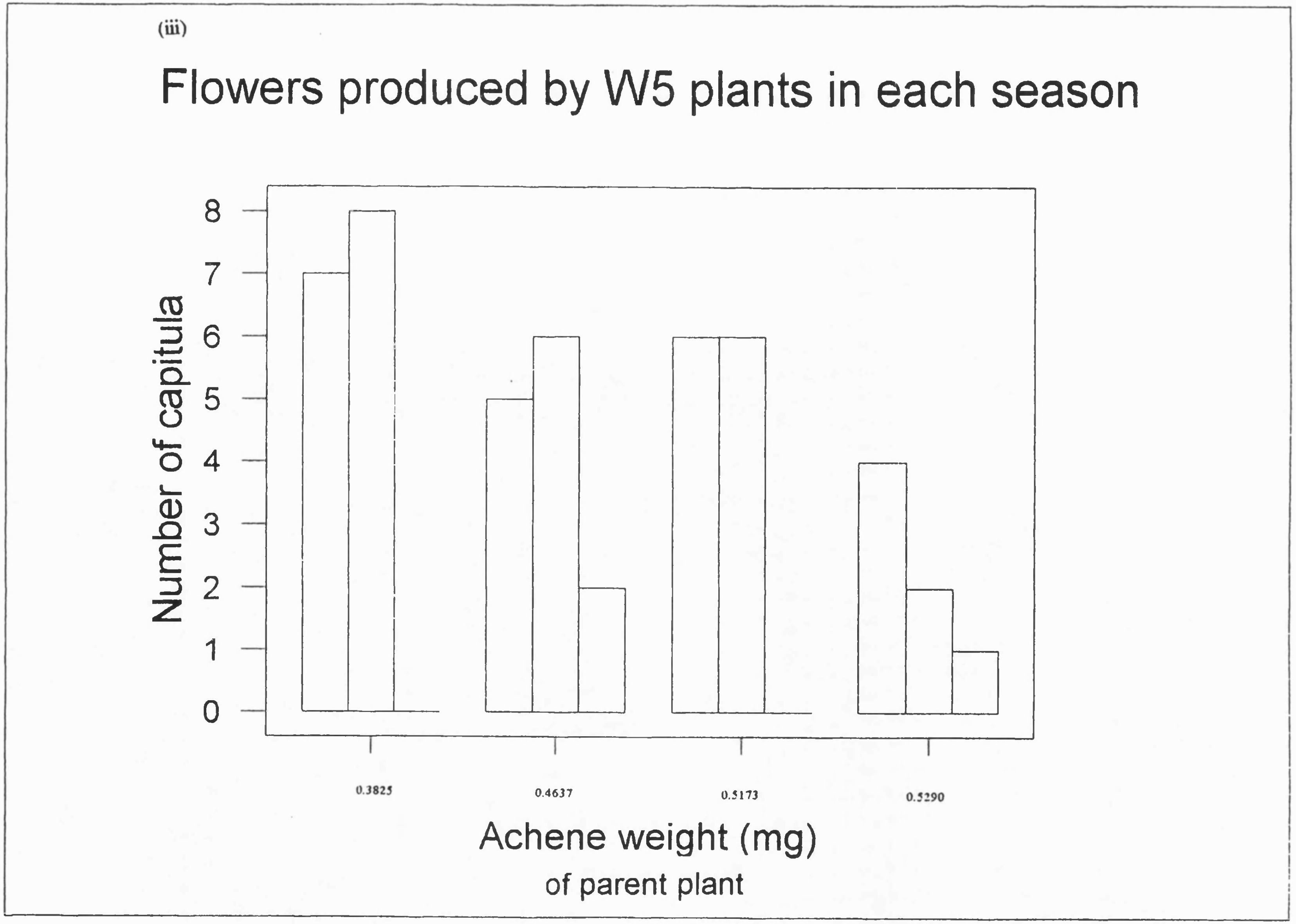
Figure 15 (i)

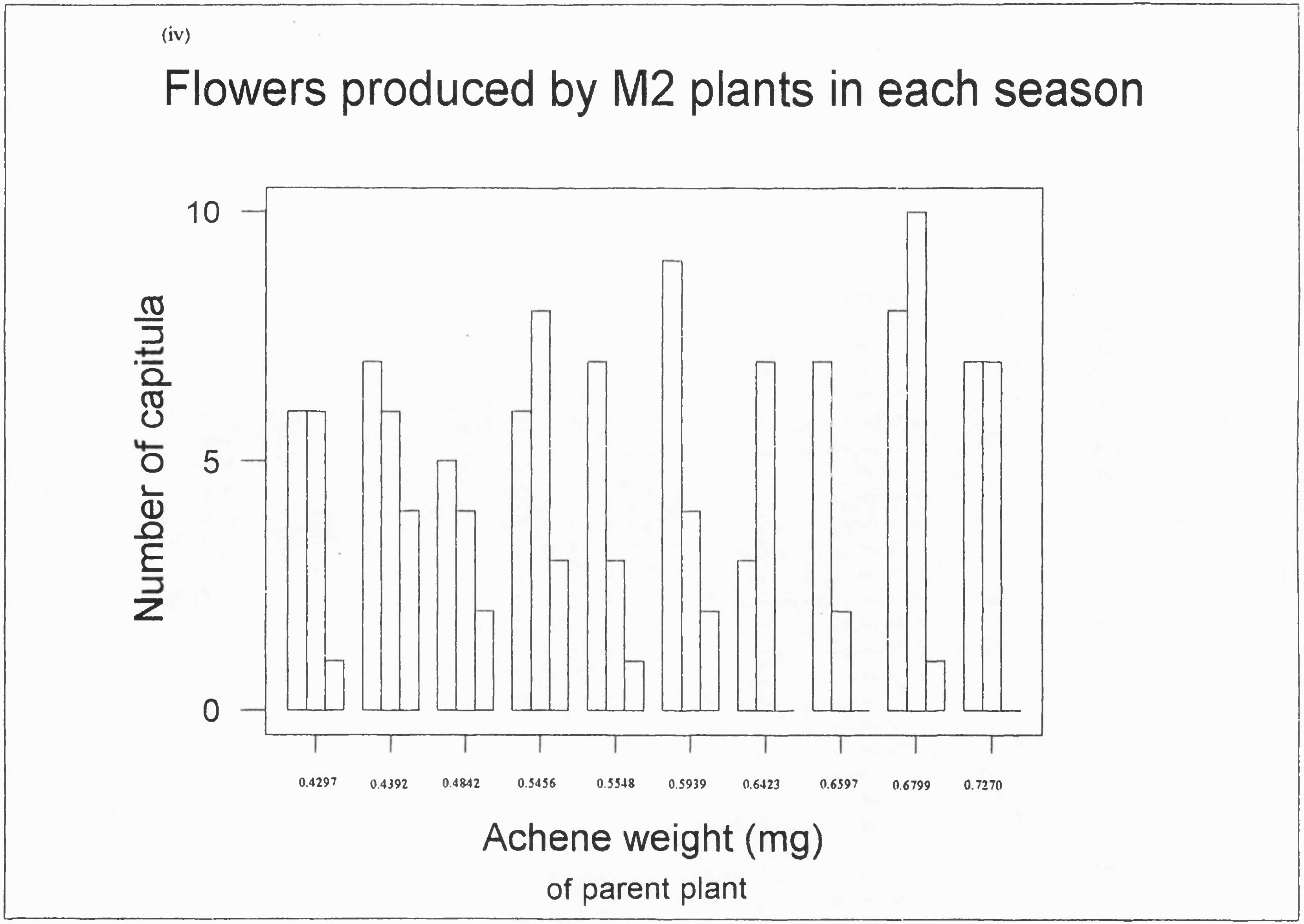
Flowers produced by W1 plants in each season



NB
The first bar in the block of three refers to number of capitula produced in the first flowering period in May 1992 (plants 120-130 days old). The second corresponds to number of capitula produced in the second flowering period in August 1992 (plants 190 days old) and the third to the number of capitula produced in the third flowering period between December 1992 and April 1993 (plants over 350 days old).


(ii)
Flowers produced by W3 plants in each season
Number of capitula
0
1
2
3
4
5
6
7
8
0.4623
0.6244
0.6828
0.7681
0.7928
0.8039
0.8235
0.8443
0.8482
Achene weight (mg)
of parent plant


(iii)
Flowers produced by W5 plants in each season
Number of capitula
0
1
2
3
4
5
6
7
8
0.3825
0.4637
0.5173
0.5290
Achene weight (mg)
of parent plant


(iv)
Flowers produced by M2 plants in each season
Number of capitula
0
5
10
0.4297
0.4392
0.4842
0.5456
0.5548
0.5939
0.6423
0.6597
0.6799
0.7270
Achene weight (mg)
of parent plant

of capitula produced in different periods. To find if there is a cost of reproduction (Law,1979) for plants that flowered in both years (i.e. clones W1,W3,W5 and M2), the number of capitula produced in the second year (spring 1993, named season 2) was plotted against the number produced in both flowering periods in 1992 (named season 1). See Figure 16 (i)-(iii). A regression was performed for each plot, of which only the data for W1 showed a marginally significant trend, (p $\approx$5%; r^2(adjusted) = 32.0% - 35.2%). This clone showed a decrease in capitula number for the second season when capitula for the first season increased. The other 3 clones showed no significant trends. All except M2 had a negative regression slope. A summary of the results is shown in Table 24.

Table 24 Regression Analysis for each clone over two seasons.

(i) Capitula production over two seasons

(the regression equation follows the general form y=mx+c, so the slope(m) and intercept (c) only are given)

Clone	Slope (m)	Intercept (c)	r^2 (adj)	p(df)
W1	-0.385	9.55	35.2%	0.054(1,8)
W3	-0.156	3.3	0.0%	0.620(1,7)
W5	-0.119	2.06	0.0%	0.535(1,2)
M2	0.101	0.17	0.0%	0.560(1,8)

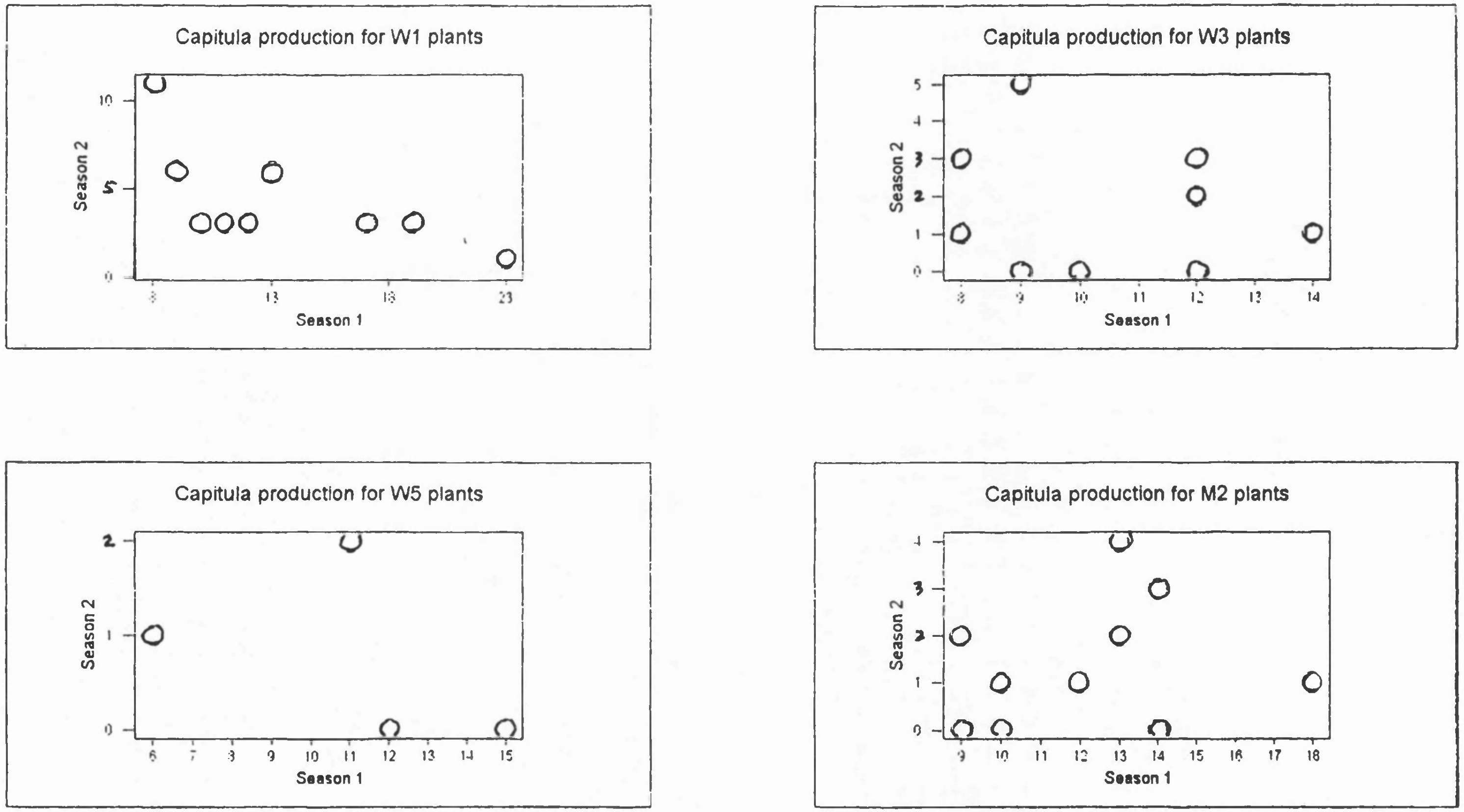
(ii) Viable achene production

Clone	Slope (m)	Intercept (c)	r^2 (adj)	p(df)
W1	-0.454	1520	33.6%	0.046(1,8)
W3	-0.12	428	0.0%	0.673(1,7)
W5	-0.1	340	0.0%	0.638(1,2)
M2	0.0688	-33	2.5%	0.300(1,8)

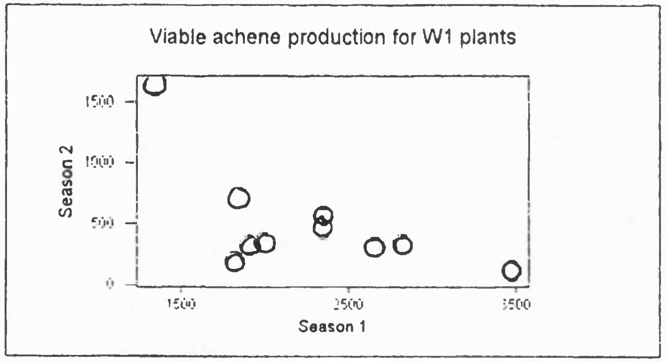
(iii) Total achene weight

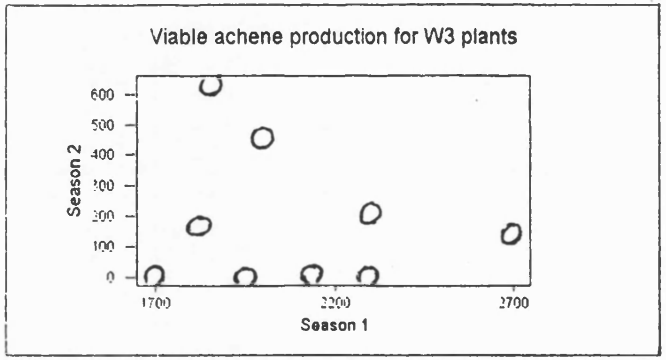
Clone	Slope (m)	Intercept (c)	r^2 (adj)	p(df)
W1	-0.323	0.709	32.0%	0.051(1,8)
W3	-0.141	0.211	4.9%	0.273(1,7)
W5	-0.032	0.081	0.0%	0.880(1,2)
M2	0.065	-0.0169	1.9%	0.310(1,8)

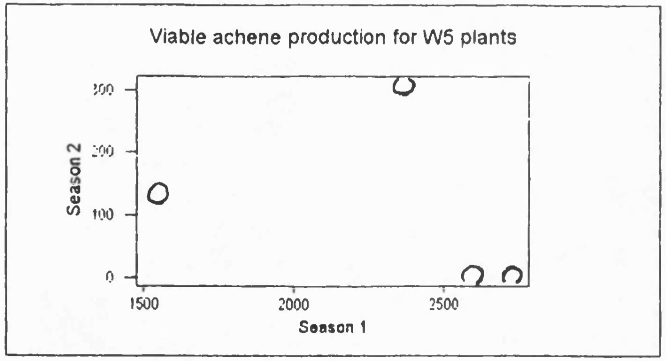
Figure 16 (i)Capitula production over 2 seasons

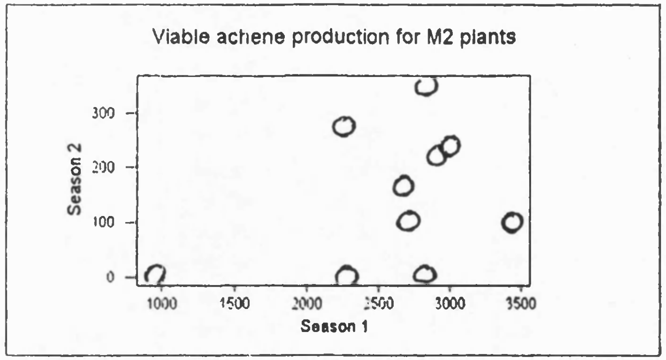


(ii) Viable achene production over 2 seasons

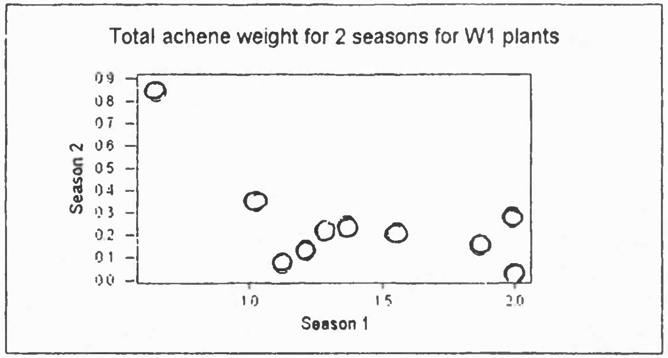


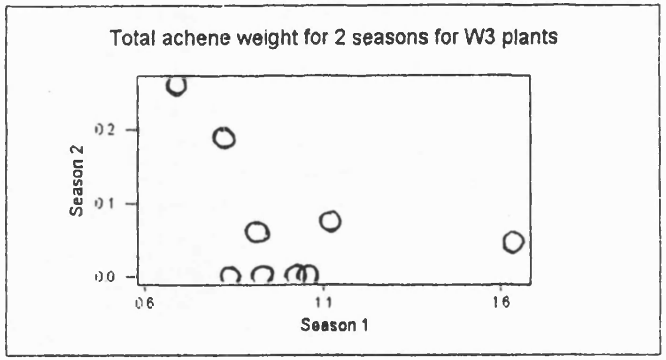


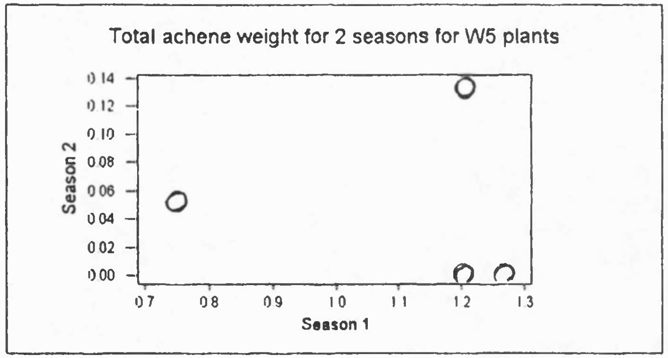


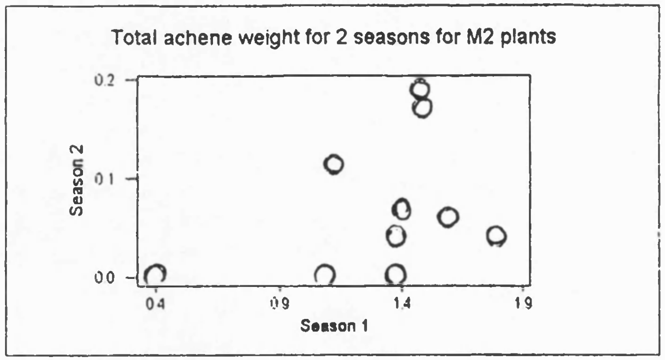


(iii) Total achene weight produced in 2 consecutive seasons









Total achene weight for each season is given in grammes

To ascertain the most appropriate regression equation to describe the data set fully, exploratory analyses were carried out on half the data set (i.e. on data from 40 plants). Regression equations were calculated for : total number of achenes per capitulum against plant age (in days); flower number (position of capitulum in flowering sequence); both of these factors (combining age and flower number into a multiple regression); and number of viable achenes per capitulum against the same 3 predictors. This gave 6 equations for each plant. As an example, Table 25 shows the results for W1/83.

Table 25 Regression Analysis for W1/83

Where t = total number of achenes per capitulum, pa = plant age, c = capitulum number, and v = number of viable achenes per capitulum.

Regression equation	p(df)	r^2 (adj)
t = 340-0.54pa	0.015(1,11)	37.7%
t = 385-23.3c	0.000(1,11)	71.2%
t = 379-31.2f+0.28pa	0.001(1,11)	71.8%
v = 269-0.406pa	0.028 (1,11)	31.1%
v = 306-18.1c	0.000(1,11)	64.8%
v = 301-25.9f+0.274pa	0.002(1,11)	66.5%

The equation which consistently gives the highest r^2(adj) value, and therefore the best description, is that for total number of achenes per capitulum against capitulum number. This is the one that will be quoted in Table 27. Similarly, for the same 40 plants, correlations were calculated between plant age and 1) total achenes; 2) number of viable achenes; 3) total weight of achenes; and 4) mean weight of achenes in the corresponding capitulum and the same 4 factors against flower number. For W1/83 the correlations are given in Table 26.

Table 26 Correlation coefficients for W1/83 for the parameters measured.

	total achenes	number viable	total achene weight/capitulum	mean achene weight/capitulum
plant age	-0.655	-0.607	-0.572	0.138
capitulum number	-0.858	-0.823	-0.821	-0.147

Again the correlation between capitulum number and total achenes per capitulum gives the most consistent figure, so this is the one that will also be quoted in Table 27.

Table 27 Summary of flowering characteristics of all plants in the experiment.

The linear regression equations follow the general form y = mx + c and in the subsequent tables only the slope (m) and intercept (c) will be presented. Correlation coefficients between capitulum number and total achenes per capitulum are also included.

(1) W1 plants

Plant code	Plant achene wt (mg)	Total number achenes	Total viable achenes	Total weight achenes (g)	Number flowers	Slope (m)	Intercept (c)	r^2 (adj)	p(df)	Correlation
W1/15	0.4626	3,315	2,795	2.265	15	-17.7	363	55.0%	0.001(1,13)	-0.763
W1/24	0.5202	3,072	2,222	1.343	14	-18.8	360	77.9%	0.000(1,12)	-0.892
w1/70	0.7447	4,050	3,145	2.0216	21	-11.9	324	70.6%	0.000(1,19)	-0.849
W1/83	0.7741	2,889	2,338	1.5032	13	-23.2	385	71.2%	0.001(1,11)	-0.858
W1/93	0.7913	4,115	2,969	1.4561	19	-8.64	303	20.6%	0.029(1,17)	-0.5
W1/114	0.8569	4,270	2,969	1.766	20	-13.4	354	77.3%	0.000(1,18)	-0.886
W1/115	0.8673	3,851	2,911	1.6085	19	-15.9	362	71.9%	0.000(1,17)	-0.867
W1/116	0.8589	3,611	2,854	1.3754	15	-10.5	325	13.3%	0.099(1,13)	-0.442
W1/136	0.9255	4,908	3,581	2.0254	24	-12	354	73.1%	0.000(1,22)	-0.862
W1/139	0.934	2,508	2007	1.1993	9	-37.4	466	89.4%	0.000(1,7)	-0.953

(2) W2 plants

Plant code	Plant achene wt (mg)	Total achene number	Total viable achenes	Total weight achnenes (g)	Number flowers	Slope (m)	Intercept (c)	r^2 (adj)	p(df)	Correlation
W2/114	0.9725	1,226	1,176	0.6556	7	-18.9	251	32.4%	0.106 (1,5)	-0.661
W2/125	1.0151	1,734	1,627	1.0182	9	-12.8	257	4.5%	0.279(1,7)	-0.405
W2/168	1.1719	1,052	997	0.6074	5	-26.8	291	7.9%	0.330(1,3)	-0.556
W2/189	1.2255	1,155	1,094	0.4393	7	-5.11	185	0.0%	0.417(1,5)	-0.368

(3) W3 plants

Plant code	Plant achene wt (mg)	Total achene number	Total viable achenes	Total weight achenes (g)	Number flowers	Slope (m)	Intercept (c)	r^2 (adj)	p(df)	Correlation
W3/20	0.4623	2,107	1,990	0.9751	9	-43	449	72.9%	0.000(1,7)	-0.873
W3/43	0.6244	2,679	2,451	1.011	15	-17	315	42.9%	0.005(1,13)	-0.686
W3/58	0.6828	2,233	2,129	1.0592	12	-26.9	361	84.7%	0.000(1,10)	-0.928
W3/101	0.7681	3,032	2,839	1.6983	15	-7.76	264	2.5%	0.265(1,13)	-0.308
W3/120	0.7928	2,746	2,513	1.1682	14	-22	361	75.8%	0.000(1,12)	-0.881
W3/127	0.8039	2,189	1,948	0.9312	11	-32.3	393	81.5%	0.000(1,9)	-0.913
W2/140	0.8235	2,526	2,287	1.026	10	-33.5	437	80.2%	0.000(1,8)	-0.908
W3/149	0.8443	1,864	1,698	0.839	9	-35.3	384	87.0%	0.000(1,7)	-0.942
W3/150	0.8482	2,722	2,484	0.9489	14	-18.2	331	53.7%	0.002(1,12)	-0.757

(4) W4 plants

Plant code	Plant achene weight (mg)	Total achene number	Total viable achenes	Total weight achenes (g)	Number flowers	Slope (m)	Intercept (c)	r^2 (adj)	p(df)	Correlation
W4/37	0.5387	1,410	1,303	0.4739	12	-6.05	157	39.3%	0.017(1,10)	-0.669
W4/69	0.661	964	930	0.5479	8	-2.55	132	0.0%	0.460(1,6)	-0.307
W4/72	0.669	1,378	1,250	0.6718	9	-20.4	255	24.7%	0.099(1,7)	-0.584
W4/102	0.7362	1,055	988	0.518	5	-70.5	422	66.9%	0.057(1,3)	-0.867
W4/118	0.7721	554	536	0.3191	4	-19.8	188	95.2%	0.016(1,2)	-0.984
W4/160	0.8678	1,408	1,327	0.5538	12	3.43	95	17.3%	0.099(1,10)	0.498
W4/171	0.9002	1,005	915	0.3924	4	-112	530	86.3%	0.047(1,2)	-0.953
W4/174	0.9097	1,545	1,426	0.693	9	3.8	153	0.0%	0.745(1,7)	0.127
W4/196	1.1182	565	527	0.2816	3	-38.5	265	0.0%	0.522(1,1)	-0/682

(5) W5 plants

Plant code	Plant achene weight (mg)	Total achene number	Total viable achenes	Total achene weight (g)	Number flowers	Slope (m)	Intercept (c)	r^2 (adj)	P(df)	Corrleation
W5/14	0.3825	2,988	2,728	1.2663	15	-24.6	396	68.8%	0.000(1,13)	-0.843
W5/19	0.4637	2,863	2,670	1.3387	13	-30.6	434	69.0%	0.015(1,11)	-0.846
W5/29	0.5173	2,836	2,596	1.2014	12	-38.9	489	89.4%	0.000(1,10)	-0.801
W5/33	0.529	1,826	1,679	0.8012	7	-57.1	489	81.6%	0.003(1,5)	-0.431

(6) M1 plants (regression and correlation cannot be performed where only 2 flowers were produced)

Plant code	Plant achene weight (mg)	Total achene number	Total viable achenes	Total achene weight (g)	Number flowers	Slope (m)	Intercept (c)	r^2 (adj)	p(df)	Correlation
M1/23	0.6243	171	89	0.0565	2	-	-	-	-	-
M1/31	0.6986	160	144	0.0368	2	-	-	-	-	-
M1/74	0.7984	320	311	0.2038	3	19.5	67.7	88.1%	0.157(1,1)	0.97
M1/115	0.8665	391	338	0.1724	3	6.5	117	0.0%	0.863(1,1)	0.214
M1/116	0.8667	317	301	0.1223	3	-21	148	53.6%	0.32(1,1)	-0.876
M1/118	0.8736	534	517	0.1413	5	-2.5	114	0.0%	0.788(1,3)	-0.167
M1/119	0.8811	371	347	0.1585	4	-5.1	106	0.0%	0.566(1,2)	-0/444
M1/136	0.9542	775	747	0.3797	6	-20.7	201	36.9%	0.119(1,4)	-0.704

(7) M2 plants

Plant code	Plant achene weight (mg)	Total achene number	Total viable achenes	Total achene weight (g)	Number flowers	Slope (m)	Intercept (c)	r^2 (adj)	p(df)	Correlation
M2/21	0.4294	2,990	2,814	1.4208	13	-31.8	453	86.4%	0.000(1,11)	-0.935
M2/26	0.4392	3,424	3,188	1.659	17	-24.2	419	81.3%	0.000(1,15)	-0.908
M2/36	0.4842	2,731	2,531	1.276	11	-32.2	441	76.1%	0.000(1,9)	-0.886
M2/46	0.5456	3,315	3,135	1.6669	17	-25.2	422	76.0%	0.000(1,15)	-0.881
M2/49	0.5548	3,016	2,844	1.4708	11	-37.9	502	70.1%	0.000(1,9)	-0.855
M2/59	0.5939	3,431	3,228	1.6502	15	-23.5	417	82.2%	0.000(1,13)	-0.913
M2/96	0.6423	1,389	956	0.3942	10	-24.2	272	74.5%	0.000(1,8)	-0.879
M2/104	0.6594	2,470	2,280	1.0885	9	-33	440	60.5%	0.008(1,7)	-0.809
M2/111	0.6799	3,772	3,535	1.8311	19	-22.5	423	80.2%	0.000(1,17)	-0.902
M2/137	0.727	3,011	2,822	1.3742	14	-28	425	86.3%	0.000(1,12)	-0.935

(8) M3 plant

Plant code	Plant achene weight (mg)	Total achene number	Total viable achenes	Total achene weight (g)	Number flowers	Slope (m)	Intercwept (c)	r^2 (adj)	p(df)	Corrlation
M3/30	0.5209	468	376	0.1666	4	-8.4	138	76.0%	0.083(1,2)	-0.917

(9) M5 plants

Plant code	Plant acheme weight (mg)	Total achene number	Total viable achenes	Total achene weight (g)	Number flowers	Slope (m)	Intercept (c)	r^2 (adj)	p(df)	Correlation
M5/50	0.8236	2,094	2,049	1.1846	9	-13.1	298	34.6%	0.056(1,7)	-0.654
M5/67	0.915	2,264	2,237	1.7953	10	5.56	196	35.0%	0.042(1,8)	0.065
M5/93	0.9617	1,873	1,841	1.0233	9	-2.55	221	0.0%	0.4(1,7)	-0.321

(10) S1 plants

Plant code	Plant achene weight (mg)	Total achene number	Total viable achenes	Total achene weight (g)	Number flowers	Slope (m)	Intercept (c)	r^2 (adj)	p(df)	Correlation
S1/58	0.6639	769	700	0.2822	5	-16.6	204	22.2%	0.239(1,3)	-0.646
S1/134	0.8976	1,233	1,137	0.4225	6	-0.9	209	0.0%	0.981(1,4)	-0.013
S1/199	0.9758	2,132	1,800	0.7813	12	-4.99	210	14.7%	0.12(1,10)	-0.473

(11) S2 plants

Plant code	Plant achene weight (mg)	Total achene number	Total viable achenes	Total achene weight (g)	Number flowers	Slope (m)	Intercept (c)	r2 (adj)	p(df)	Corrleation
S2/94	0.7749	1,954	1,816	0.9894	10	-19.3	301	15.3%	0.144(1,8)	-0.497
S2/122	0.9027	2,031	1,950	1.0088	9	1.5	218	0.0%	0.921(1,7)	0.039
S2/160	1.0406	1,356	1,217	0.5043	9	-17.1	236	9.7%	0.215(1,7)	-0.458
S2/181	1.1194	2,073	1,989	0.985	15	0.67	133	0.0%	0.609(1.13)	0.144
S2/211	1.3116	432	427	0.1634	3	11.5	121	98.9%	0.048(1,1)	0.997

(12) S3 plants

Plant code	Plant achene weight (mg)	Total achene number	Total viable achenes	Total achene weight (g)	Number flowers	Slope (m)	Intercept (c)	r^2 (adj)	p9df)	Correlation
S3/134	0.9014	1,838	1,776	0.6354	13	-6.4	186	5.0%	0.227(1,11)	-0.36
S3/137	0.9038	1,169	1,130	0.5855	9	1.3	123	0.0%	0.806(1,7)	0.096
S3/153	0.9209	366	359	0.2561	3	-22.5	167	60.0%	0.295(1,1)	-0.894
S3/191	0.9732	973	926	0.6638	8	0.39	120	0.0%	0.941(1,6)	0.032
S3/211	1.025	1,091	1,061	0.661	5	-5.4	234	0.0%	0.866(1,3)	-0.105

(13) S4 plants

Plant code	Plant achene weight (mg)	Total achene number	Total viable achenes	Total achene weight (g)	Number flowers	Slope (m)	Intercept (c)	r^2 (adj)	p(df)	Correlation
S4/90	0.7757	603	592	0.3996	4	-7.9	171	0.0%	0.482(1,2)	-0.518
S4/108	0.8352	597	546	0.2449	3	-88.5	376	81.1%	0.199(1,1)	-0.952

(14) S5 plants

Plant code	Plant achene weight (mg)	Total achene number	Total viable achenes	Total achene weight (g)	Number flowers	Slope (m)	Intercept (c)	r^2 (adj)	p(df)	Correlation
S5/61	0.6027	477	449	0.2465	3	19	121	0.0%	0.694(1,1)	0.462
S5/81	0.6467	1,234	1,110	0.5511	6	-9.1	237	0.0%	0.869(1,4)	-0.088
S5/103	0.6794	1,132	1,073	0.4289	6	-35.1	312	31.3%	0.145(1,4)	-0.671
S5/140	0.766	1,153	1,102	0.6631	5	-57.1	402	0.0%	0.437(1,3)	-0.459
S5/214	0.9488	876	799	0.3867	6	-18.1	209	57.0%	0.051(1,4)	-0.81

With few exceptions, slopes of the regression lines given in Table 27 are negative. This demonstrates that there is a strong tendency for the number of achenes produced per capitulum to decrease with capitulum position in the flowering sequence. The exceptions to this trend are given in Table 28.

Table 28 Regression coefficients for plants showing a positive slope.

Plant code	Slope (m)	Correlation	p
W4/160	0.343	0.498	0.099
W4/174	3.8	0.127	0.745
M1/74	19.5	0.97a	0.157
M1/115	6.5	0.214a	0.863
M5/67	5.56	0.65	0.042*
S2/122	1.5	0.039	0.921
S2/181	0.67	0.144	0.609
S2/211	11.5	0.997	0.048*
S3/137	1.3	0.096	0.806
S3/191	0.39	0.032	0.941
S5/61	19	0.462	0.694

a indicates that only 3 flowers were produced

Correlation is between total achene number and capitulum number

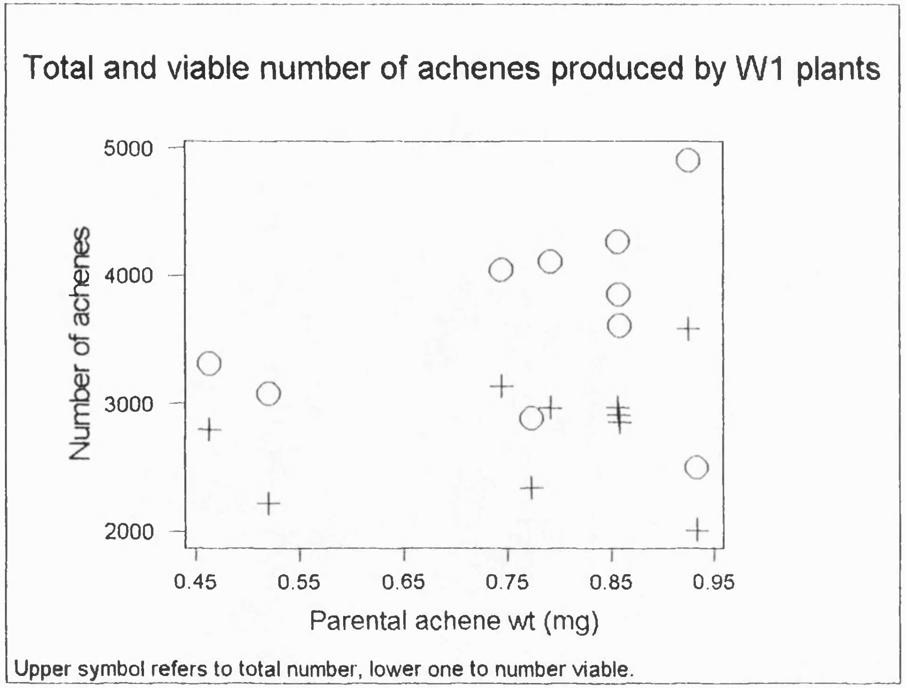
* = significant at $p<0.05$

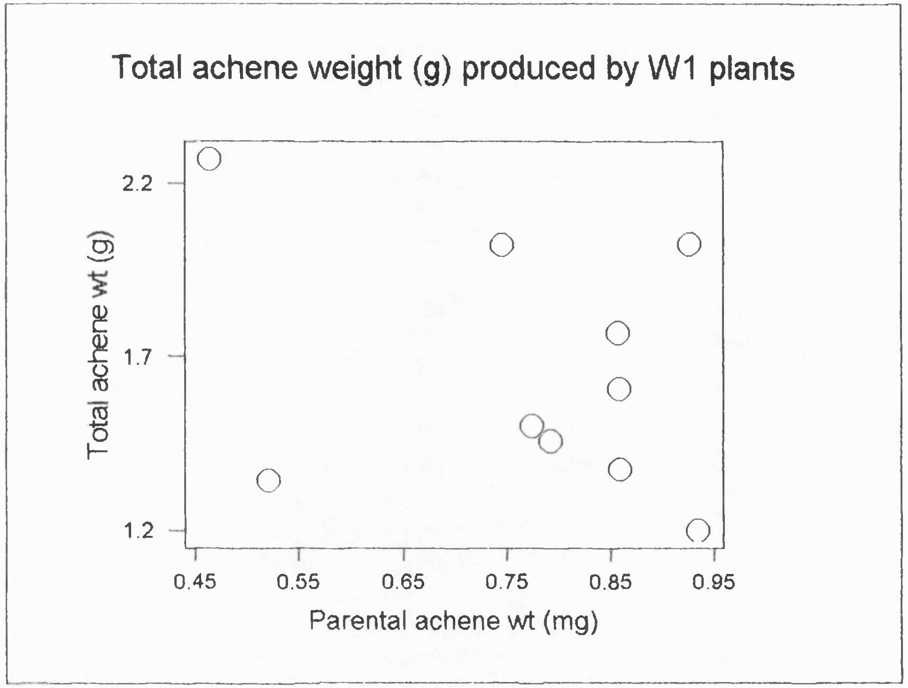
It can be seen from Tables 27 and 28 that just over 12% of the plants showed a positive correlation between the number of achenes and capitulum position in the flowering sequence.

Pairwise comparisons of the slopes of the regression lines were calculated for each clone. Within W1, all regression slopes were significantly different from each other at $p<0.01$ except for one pair (W1/70 and W1/136) that were not significantly different from each other. The regression slopes for W2 were all significantly different from each other at $p<0.01$. W3 had all pairwise comparisons significantly different at $p<0.001$. The comparisons for W4 shows them all to be significantly different at $p<0.01$ except for W4/72 and W4/118 which were not significantly different and W4/160 and W4/174 (both with positive slopes) which also were not significantly different. W5 had all pairwise comparisons of slopes significantly different at $p<0.01$. Regression slopes for M1 were all significantly different at $p<0.01$ except for M1/116 and M1/136, and M1/118 and M1/119 which were not significantly different. M2 also had two pairs of lines that differ from the rest of the clone which shows a significant difference of slopes at $p<0.01$. These are M2/21 and M2/36, and M2/26 and M2/90 which are not significantly different. All within clone pairwise comparisons for M5 and S1 are significantly different at $p<0.01$. S2 has pairwise comparisons significantly different at $p<0.01$ except for the two positive slopes (S2/122 and S2/181) which are not significantly different. S3 has pairwise comparisons that are significantly different at $p<0.01$ with two exceptions: S3/134 and S3/211, and S3/137 and S3/191 (positive slopes) are not significantly different. S4 and S5 both have within clone comparisons that are significantly different at $p<0.001$.

Of the 4 clones (W1,W3,W5 and M2) which produced capitula in each of the two seasons, only W1 showed a definite negative trend in which more capitula were produced in the first season than in the second. This trend was repeated for viable achene production and for total achene weight, the r^2 (adj) values for capitula, viable achene production and

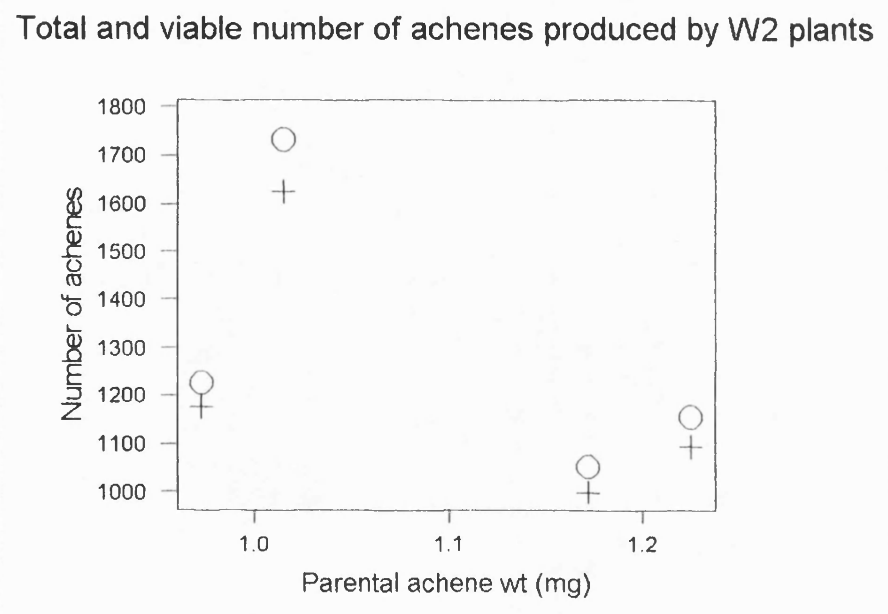
Figure 17 (i) # Achene production by W1 plants



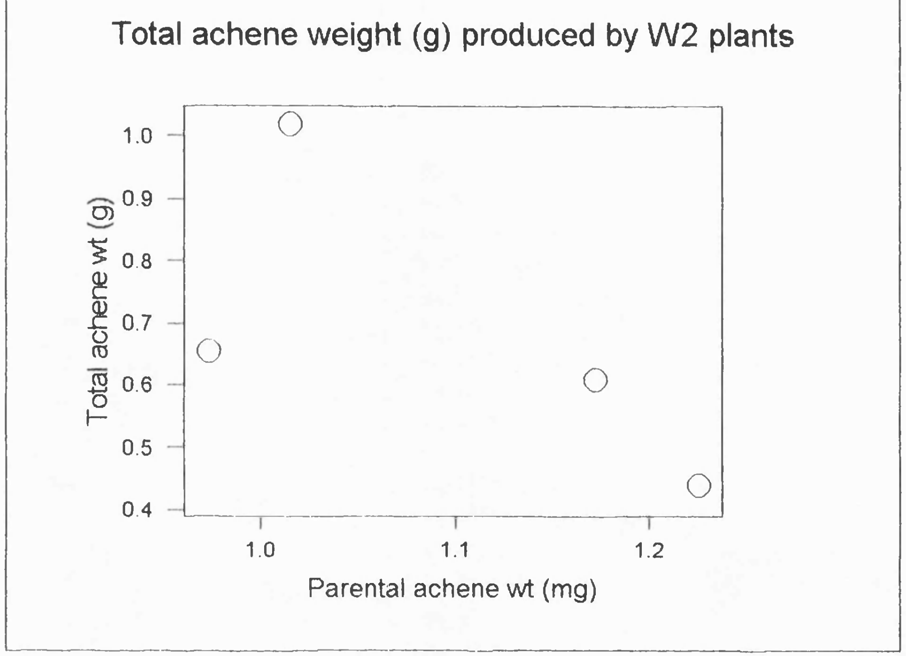


Parental achene weight refers to individual plants throughout.

(ii) Achene production by W2 plants

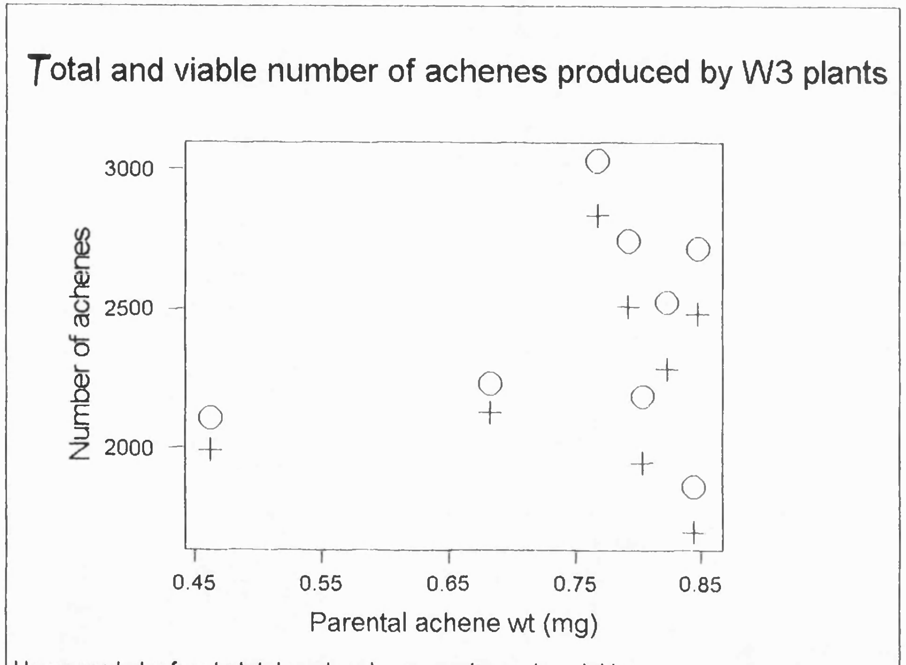


Upper symbol refers to total number, lower one to number viable.

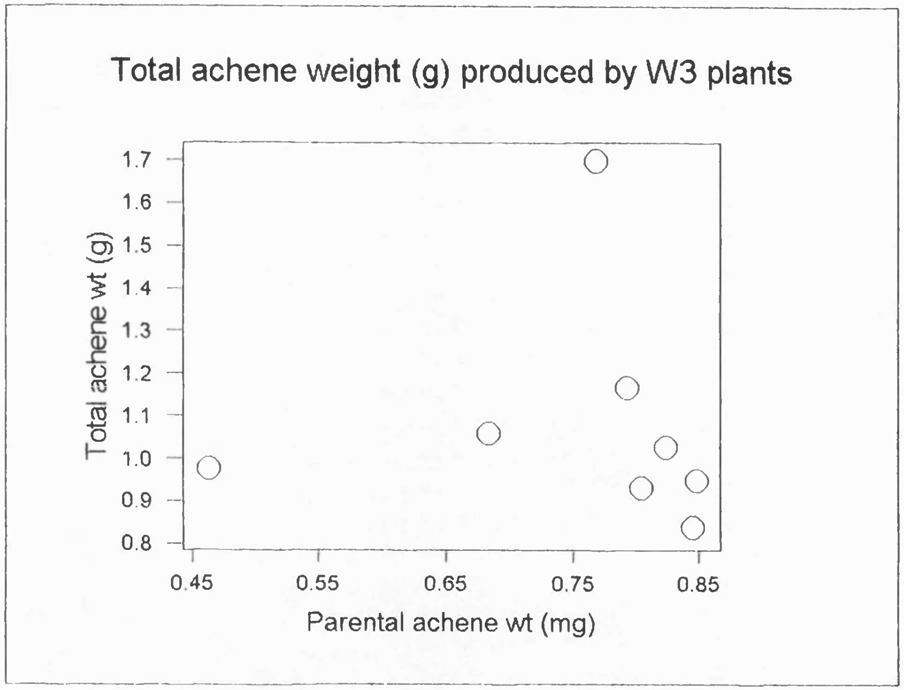


Parental achene weight refers to individual plants throughout.

(iii) Achene production by W3 plants

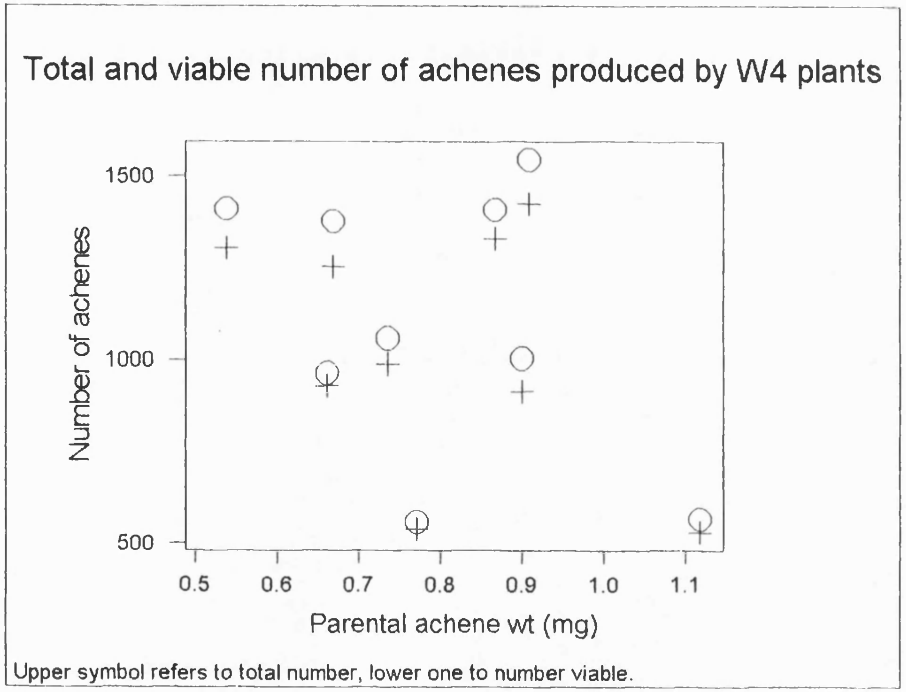


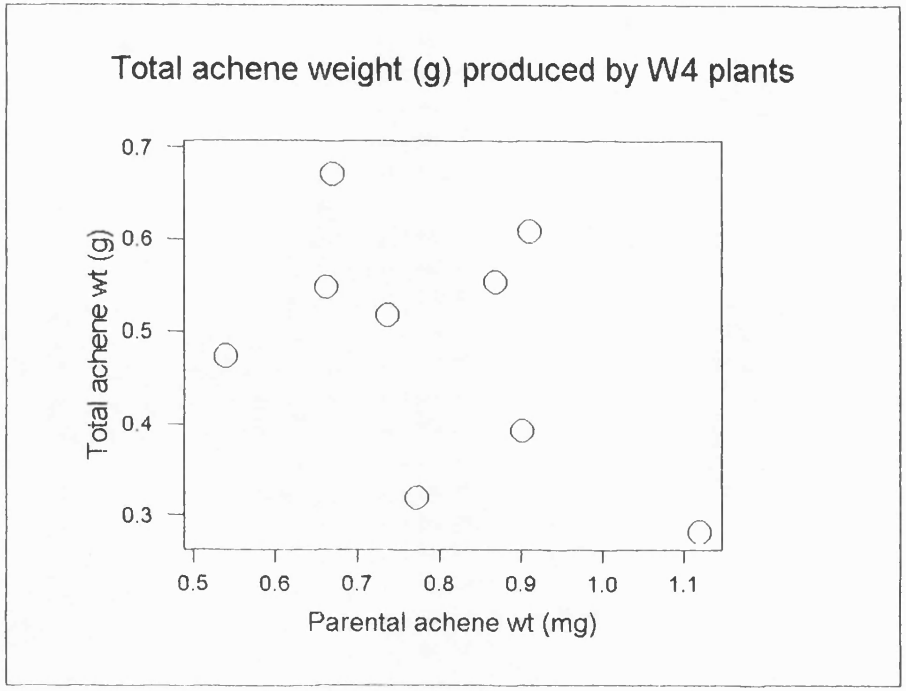
Upper symbol refers to total number, lower one to number viable.



Parental achene weight refers to individual plants throughout.

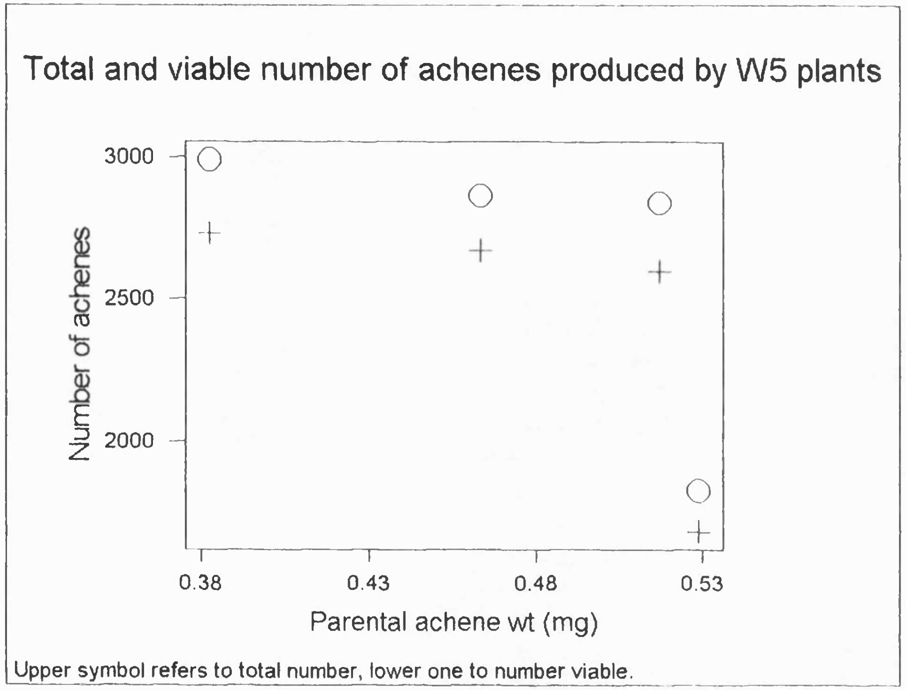
(iv) Achene production by W4 plants

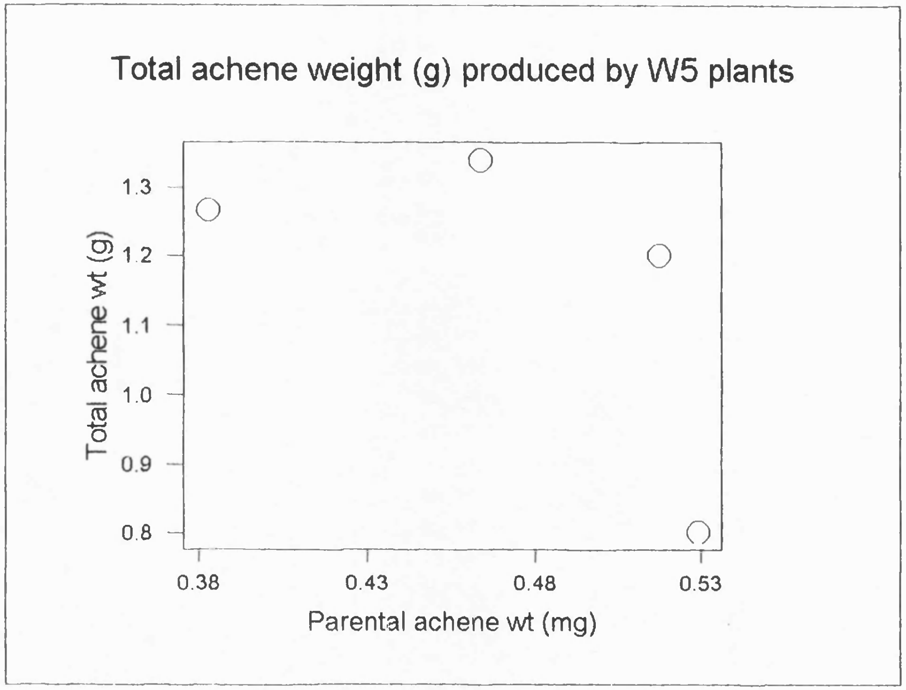




Parental achene weight refers to individual plants throughout.

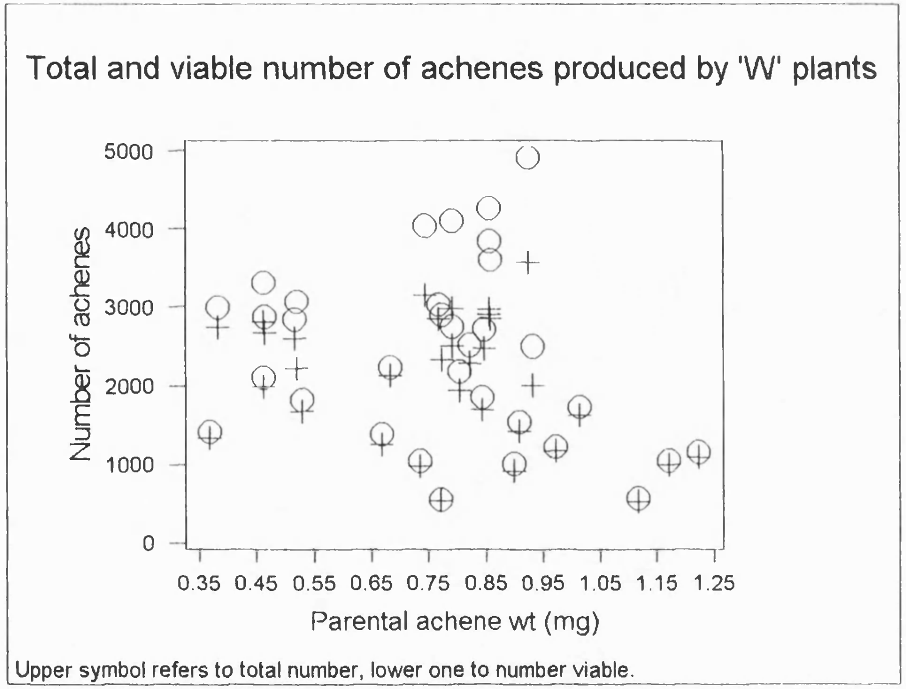
(v) Achene production by W5 plants

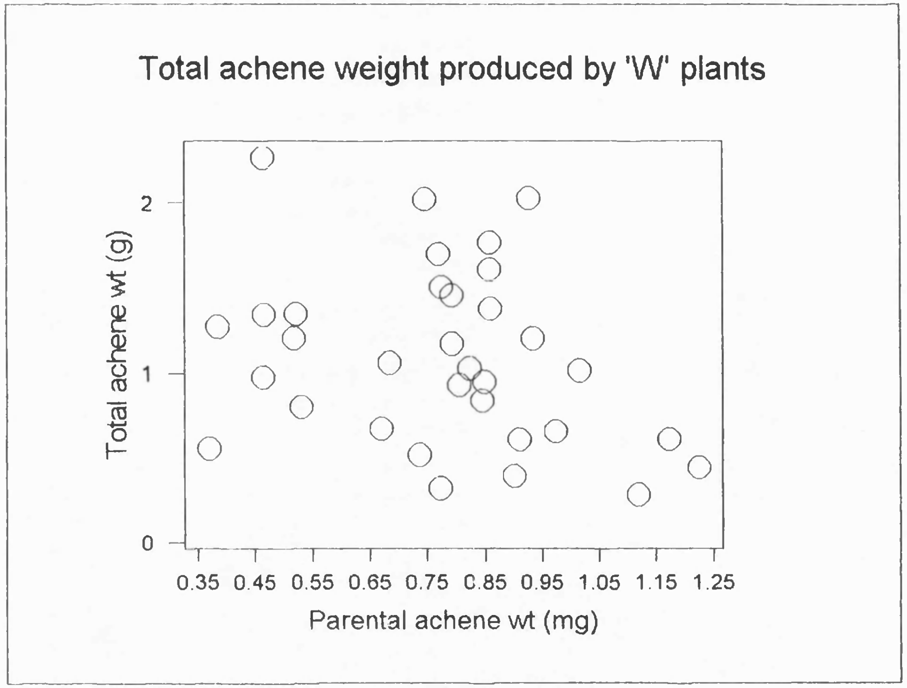




Parental achene weight refers to individual plants throughout.

(vi) Achene production by plants from W location

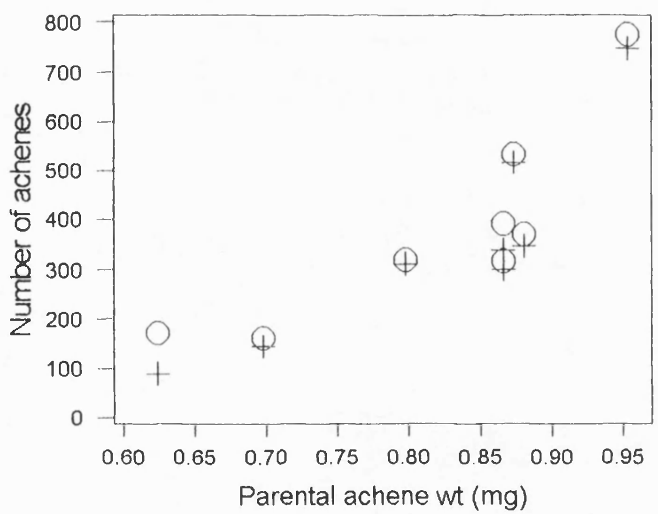




Parental achene weight refers to individual plants throughout.

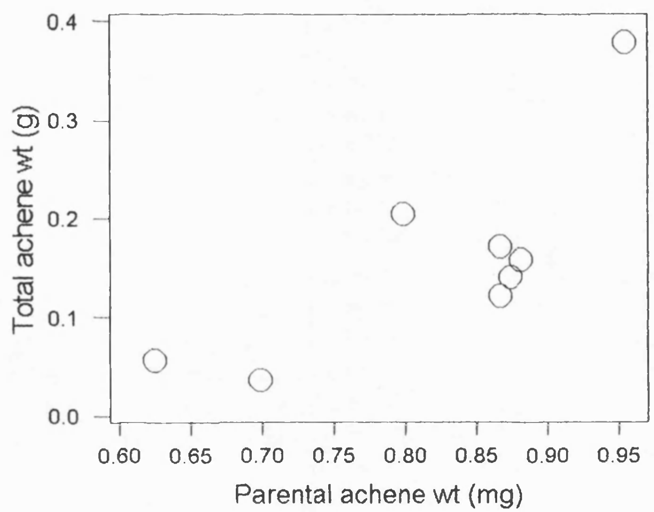
(vii) Achene production by M1 plants

Total and viable number of achenes produced by M1 plants



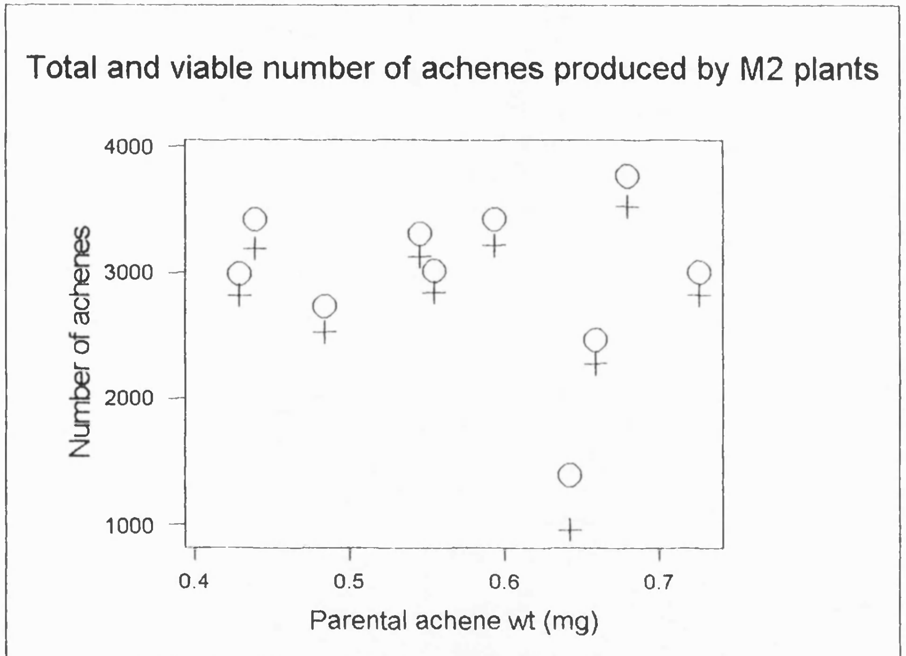
Upper symbol refers to total number, lower one to number viable.

Total achene weight (g) produced by M1 plants

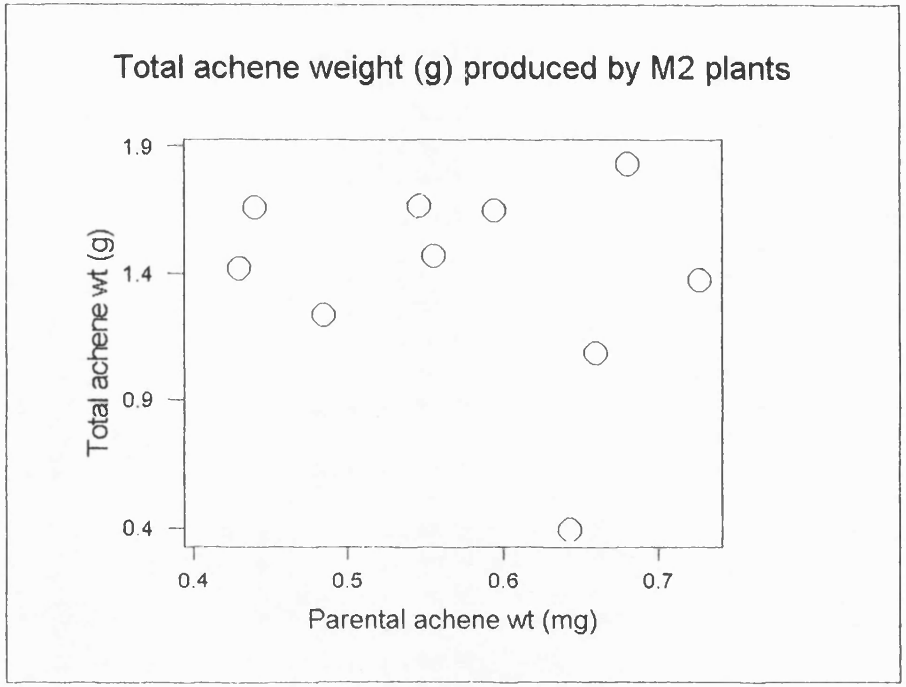


Parental achene weight refers to individual plants throughout.

(viii) Achene production by M2 plants

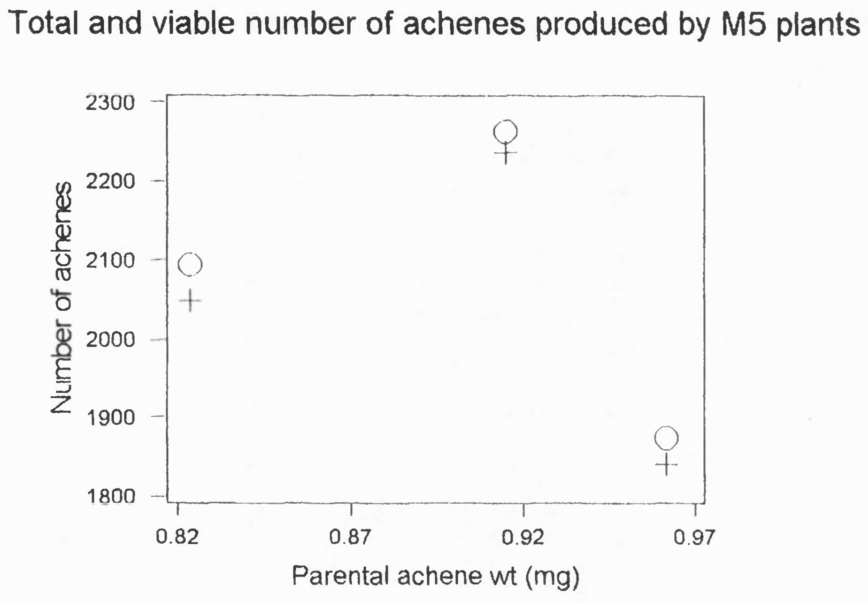


Upper symbol refers to total number, lower one to number viable.

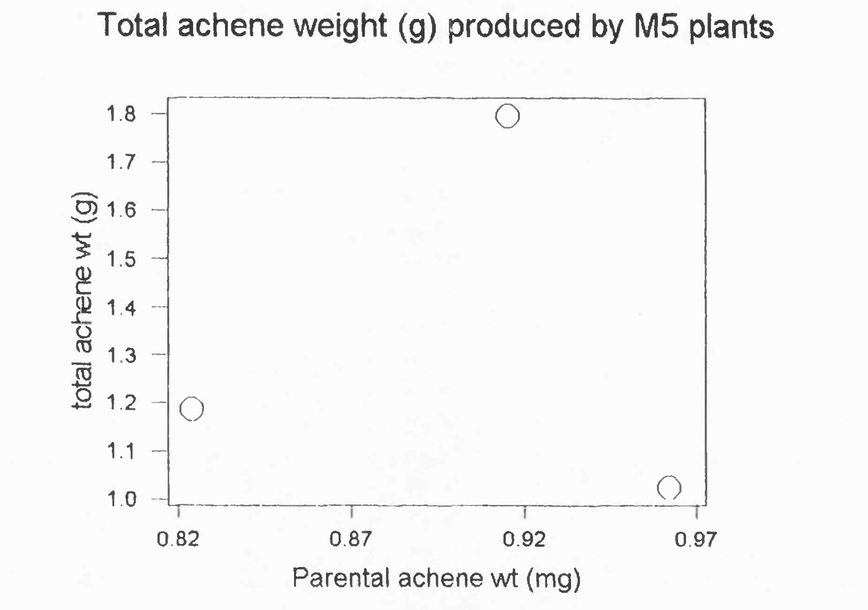


parental achene weight refers to individual plants throughout.

(ix) Achene production by M5 plants

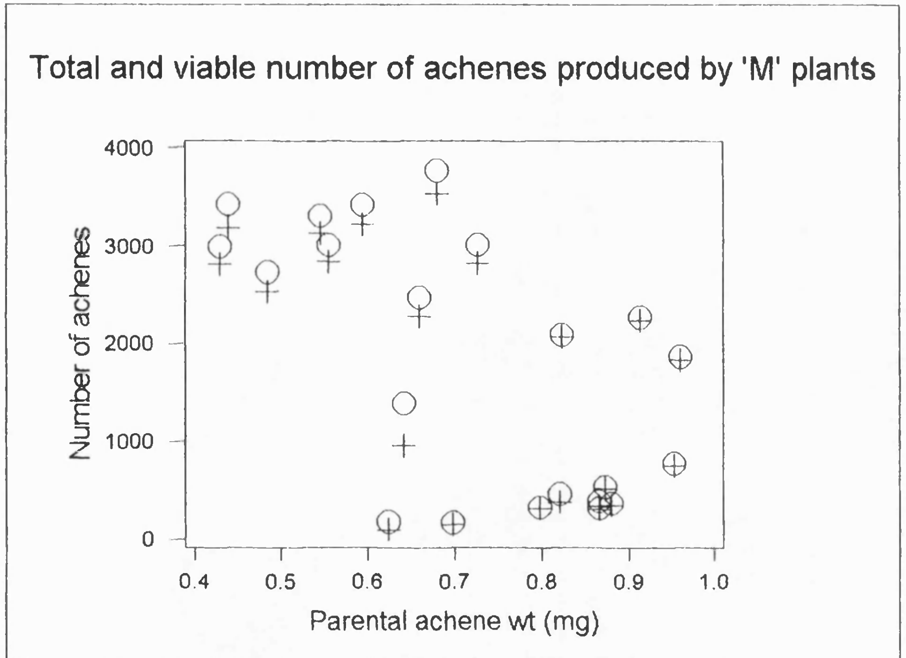


Upper symbol refers to total number, lower one to number viable.

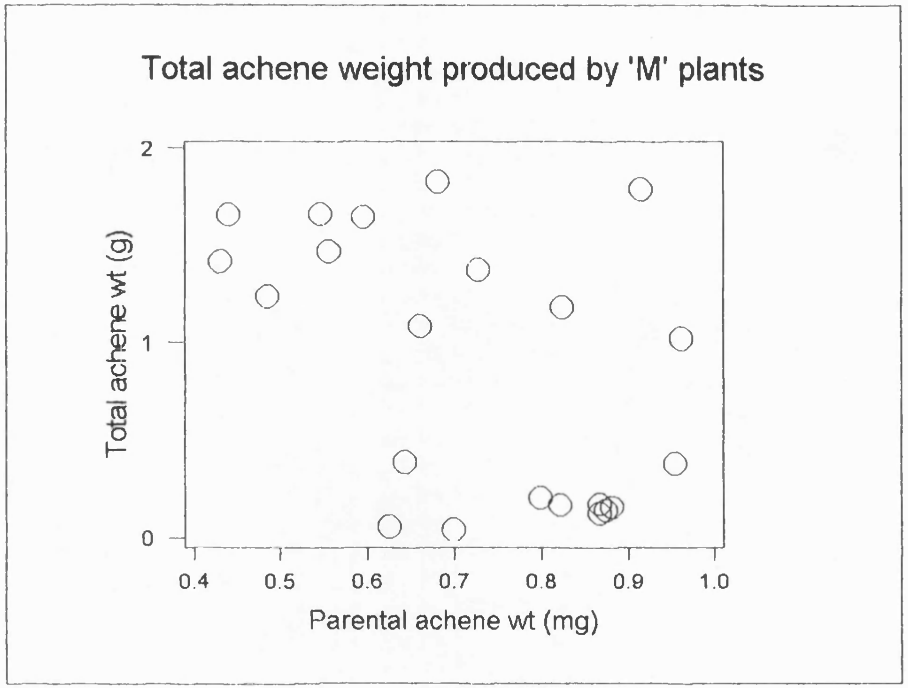


Parental achene weight refers to individual plants throughout.

(x) Achene production by plants from M location



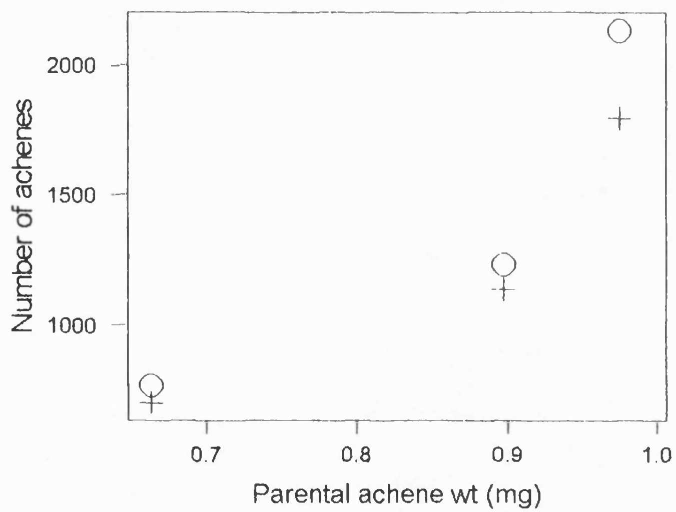
Upper symbol refers to total number, lower one to number viable.



Parental achene weight refers to individual plants throughout.

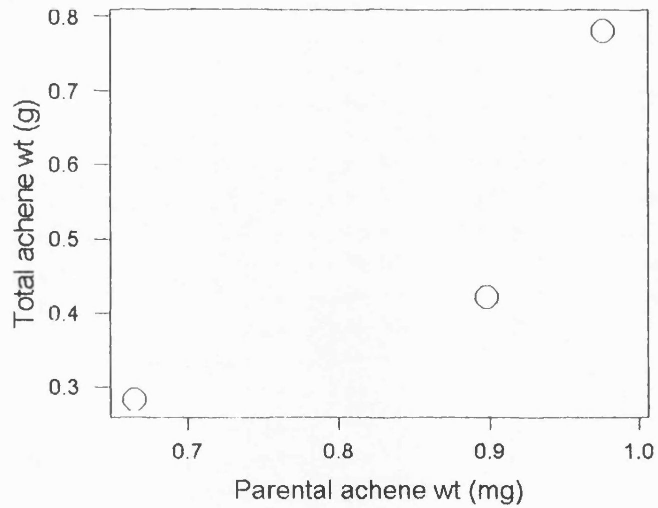
(xi) Achene production by S1 plants

Total and viable number of achenes produced by S1 plants



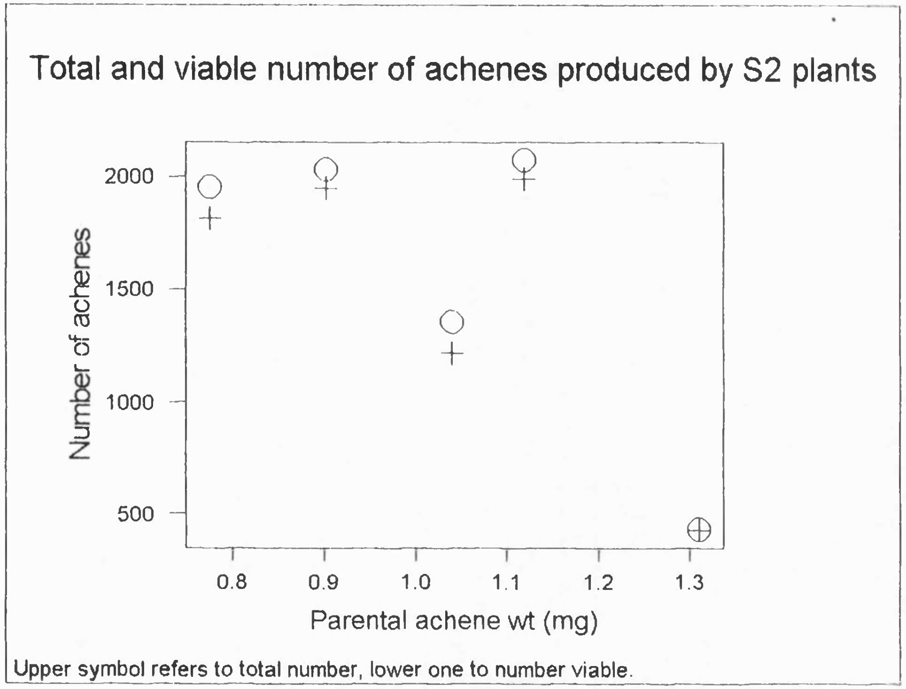
Upper symbol refers to total number, lower one to number viable.

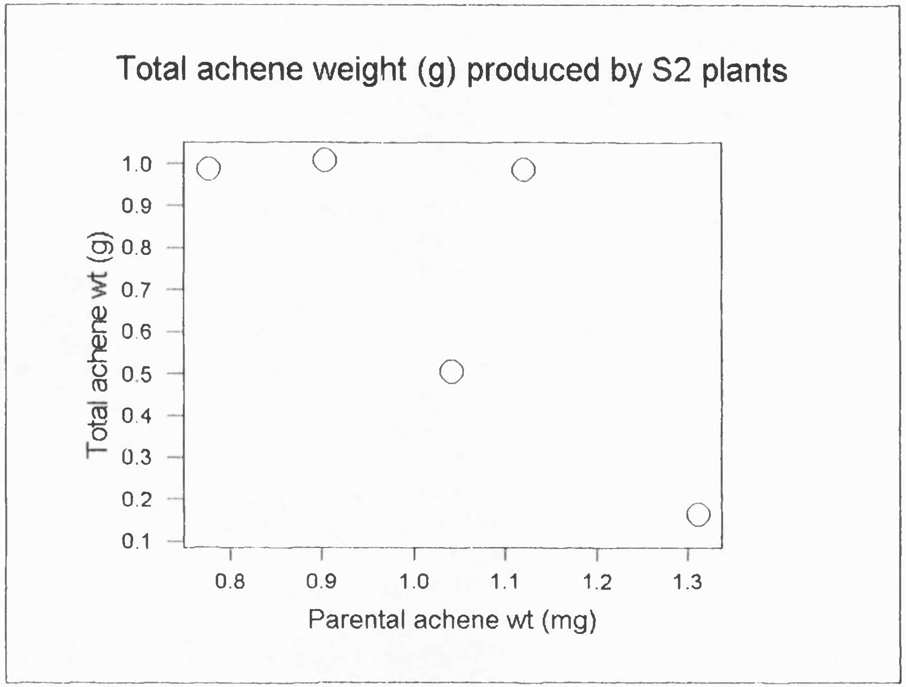
Total achene weight (g) produced by S1 plants



Parental achene weight refers to individual plants throughout.

(xii) Achene production by S2 plants





Parental achene weight refers to individual plants throughout.

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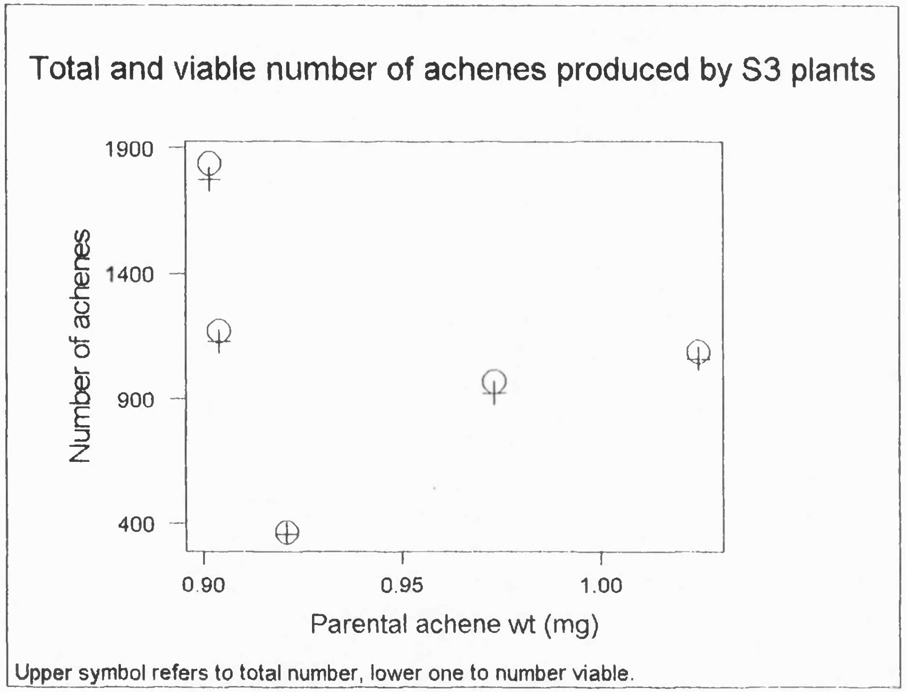
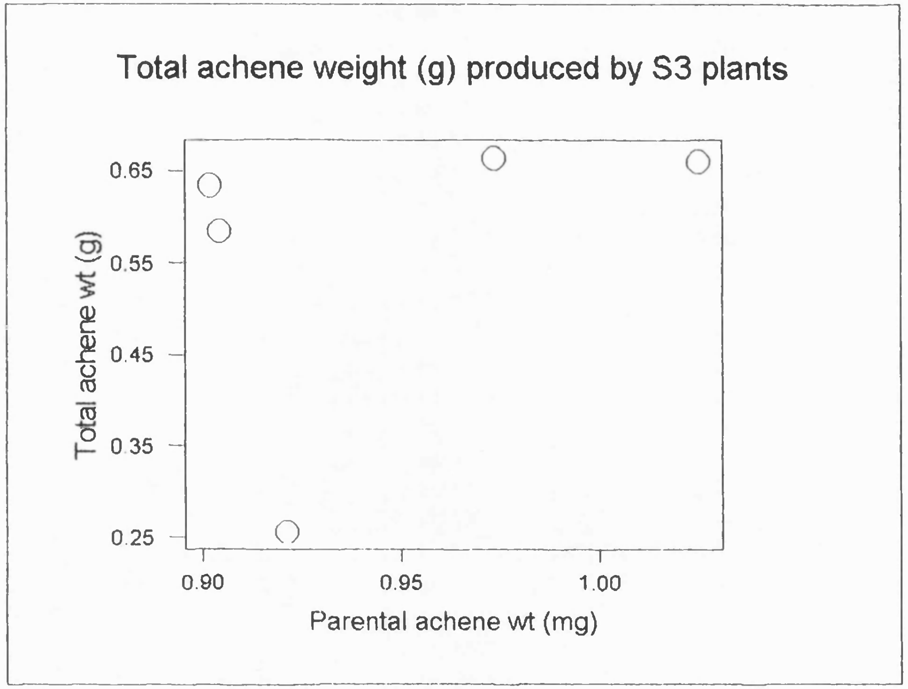
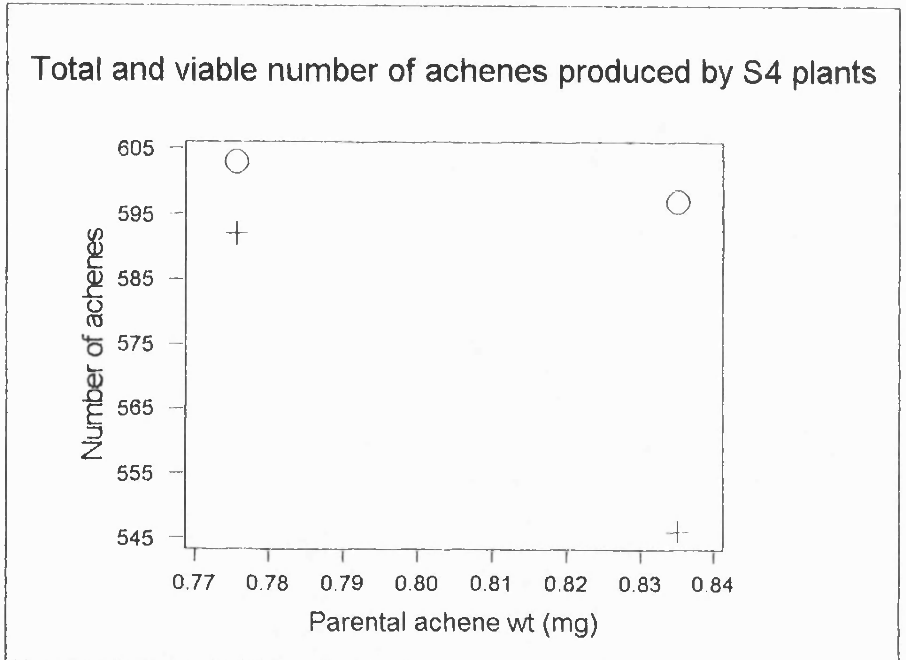
(xiii) Achene production by S3 plants



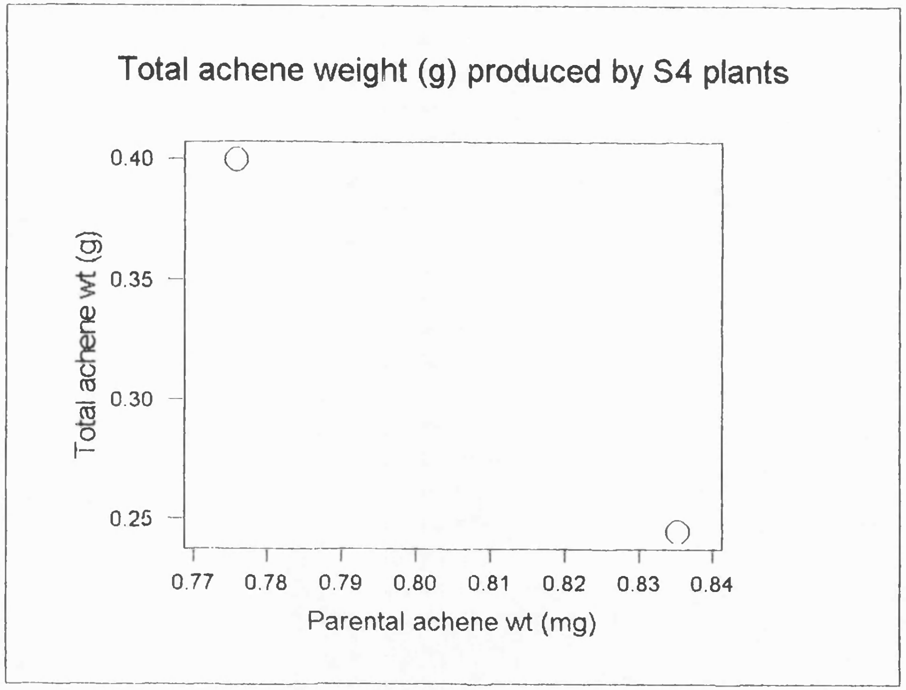


Parental achene weight refers to individual plants throughout.

(xiv) Achene production by S4 plants

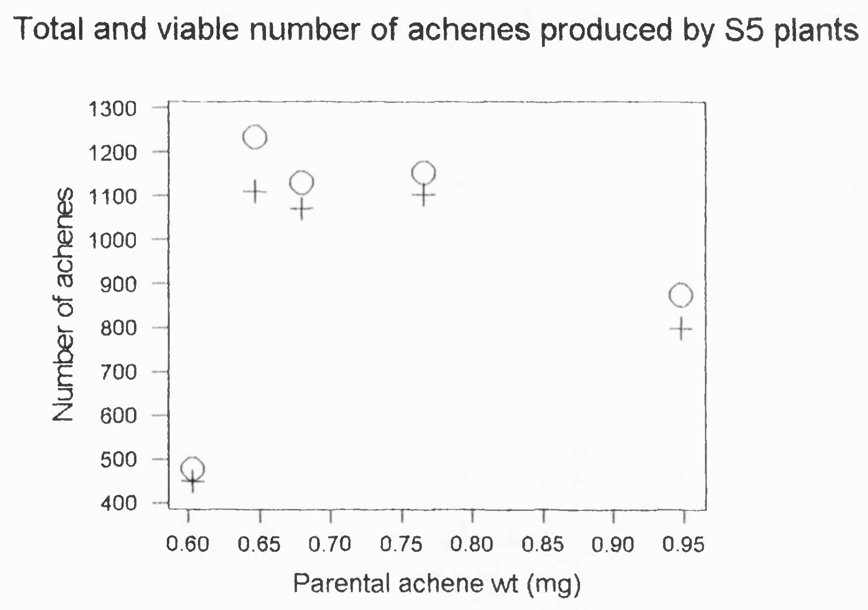


Upper symbol refers to total number, lower one to number viable.

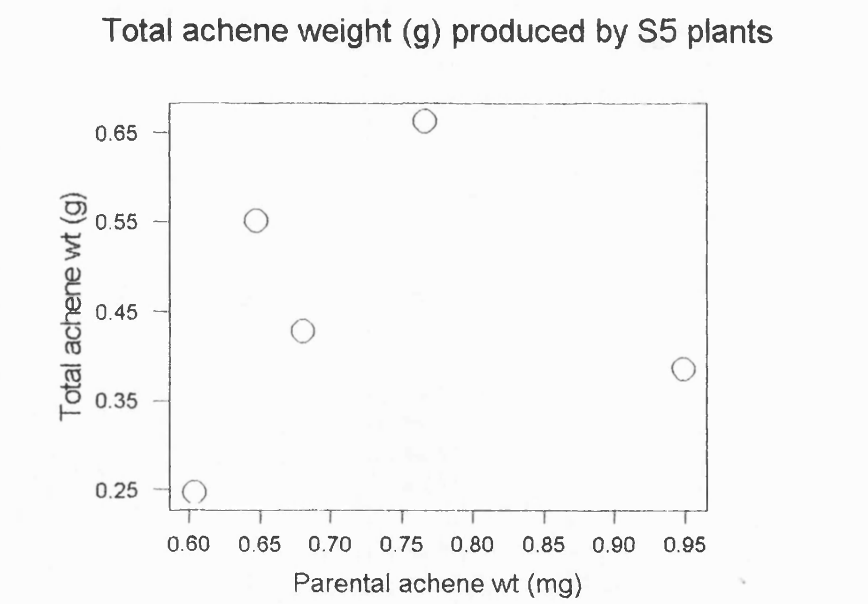


Parental achene weight refers to individual plants throughout.

(xv) Achene production by S5 plants

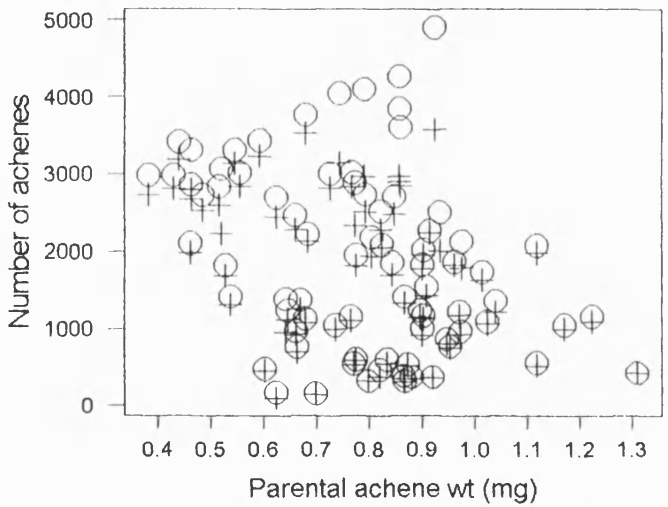


Upper symbol refers to total number, lower one to number viable.

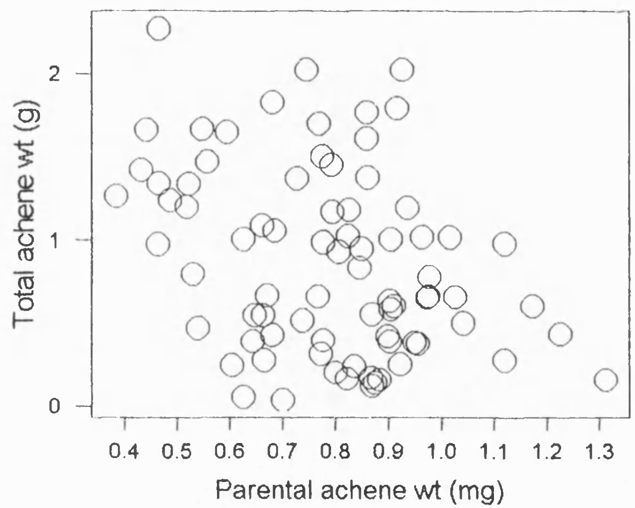


Parental achene weight refers to individual plants throughout.

(xvi) Achene production by plants from S location



Upper symbol refers to total number, lower one to number viable.



Parental achene weight refers to individual plants throughout.

total achene weight being 35.2%, 33.6% and 32.0% respectively. There are no trends for the other three clones, as can be seen from Figure 16 (i)-(iii).

Figure 17 (i)-(xvi) shows plots of total achene number, viable achene number and total achene weight against plant achene weight (i.e. the weight of achene from which the experimental plant was produced). The data are combined for each 'location' (i.e all results from W plants combined for 'W' location).

For W plants there is no tendency for plants grown from heavier achenes to produce more achenes, more viable achenes or a greater weight of achenes than plants grown from lighter achenes. Indeed, it appears from Figure 17(vi) that plants grown from achenes in the mid-range of achene weights produce more viable achenes, and heavier achenes than plants grown from the heaviest achenes. M1 shows the opposite effect, with greater achene production being recorded in plants grown from heavier achenes (Fig 17(vii)). In M2 (Fig 17(viii)) achene production does not increase with plant achene weight (the line remains more or less flat except for a 'dip' at M2/96 (0.6423mg)). The data for M5 results is unclear as there are only three plants (Fig 17(ix)). The overall picture for 'M' location (Fig 17(x)) shows no apparent relationship between parental achene weight and subsequent achene production. There are only 3 plants in the S1 clone (Fig 17(xi)). These show a positive trend. The data for S2 are unclear but may show a negative trend (Fig 17(xii)). The data for S3 are also unclear but perhaps indicate a positive trend, especially for total achene weight (Fig 17(xiii)). S4 only has two plants so no trend is indicated (Fig 17(xiv)). S5 shows a fall in production with increasing plant achene weight after a pronounced initial increase (Fig 17(xv)). The plot for 'S' location (Fig 17(xvi)) shows no apparent relationship between parental achene weight and subsequent achene production.

Plants grown from lighter achenes tend to produce a greater total achene weight than plants grown from heavier achenes. Regressions performed on the complete data set show that the relationship between total achene number and parental achene weight is significant ($p<0.002$); the relationship between the number of viable achenes produced and parental achene weight is also significant ($p<0.001$); and the relationship between the total weight of achenes produced and parental achene weight is also significant ($p<0.002$).

5.4 Discussion

No clear conclusions regarding the onset of flowering have emerged from this experiment. Not all clones flowered in the 1st season (spring and autumn 1992), but those that did commenced flowering at around 120 days. Those clones that only flowered during the 2nd season (spring 1993) produced the first flowers at around 370-380 days. This suggests clonal variation and that it is genetically controlled. Capitula production and the number of achenes produced per capitulum varies from plant to plant. Most plants have a unique slope to the regression line which describes the decrease in achene number with capitulum number. Although most plants produced the greatest total and viable numbers along with greatest total weight with the first capitulum, 12% of the plants increased achene numbers and weight with successive capitula. However, in only two of these 12% of plants is this tendency significant (at $p<0.05$). Viable achene number for most plants is close to the total number of achenes produced. However, some plants produce a large number of empty, inviable achenes. Achenes are initiated during bud formation. If resources become scarce between bud formation and flower opening, then not all of these achenes will obtain the resources needed to develop an embryo.

The analysis indicates that, overall, achene number and weight are not correlated with initial achene weight. This implies that any benefits gained from being a plant grown from a heavier achene is lost by the first flowering period. The fecundity of plants grown from lighter achenes is not compromised in any way. It is possible that there may be a relationship between initial achene weight and survivorship. However, this was not investigated.

Of the plants that flowered in two seasons only W1 produced more capitula, more viable achenes and a greater total achene weight in season 1 than in season 2. This indicates reduced fecundity in the second season. Law (1979) investigated this between-season effect in *Poa annua* L. He found that there was a negative correlation between reproduction early in life and subsequent reproduction, growth and survival. The results of capitula production and total achene weight and number over two seasons, reported in this chapter are less clear, as only four clones flowered in both seasons. However, the results are compatible with the general theory relating the profits and costs of reproduction (Gadgil and Bossert 1970; Schaffer 1974), which states that a limited supply of resources must be partitioned between all essential activities. It follows that if more resources are allocated to reproduction this will be at the expense of other activities. It would need a further study on reallocation of resources to fully substanstiate this. Overall, achene production, whether it is total achene number, total viable achene number, or total achene weight does decline with capitula number. It will be interesting to compare the flowering characteristics and achene production of these plants with those from the field experiment that is reported in the next chapter. This will make it possible to see if the trends seen here are repeated under field conditions.

Chapter 6

This chapter has two sections. The first deals with a field experiment in which the growth characteristics of clones of *Taraxacum* in a grassland environment are assessed, along with a detailed study of a subset of plants. (This approximates to growth under natural conditions). The second section investigates the growth of three clones of *Taraxacum* in nine different environments in order to obtain a measure of environmental sensitivity.

6.1. Field Experiment

6.1.1 Introduction

Early in the history of ecology it was sufficient to make field observations to generate hypotheses, but as the hypotheses accumulated they needed to be tested. As a result, ecologists are now designing and analysing field and laboratory experiments to test such hypotheses.

Conducting field experiments is not without difficulties. They may be costly and true replication may be unattainable (Hurlbert 1984; Carpenter 1990). Moreover, there is often "noise" in the data, both because the environment is heterogeneous at many scales (Dutilleul 1993) and because field measurements are often crude compared to those achieved under laboratory (and therefore controlled) conditions. All of these factors contribute unwanted variability to the experiment. Because of these problems, it is necessary that the designs and analyses of field experiments are conducted in a way that enables treatment effects to be detected with maximum reliability. Most ecological experiments are spatial in nature, but often spatial information is not used in a classical analysis of variance. To employ this method of analysis demands an adequate design of the ecological field experiment that takes into account the type and scale of heterogeneity, including small-scale heterogeneity, heterogeneity between patches and heterogeneity along one- or two-dimensional gradients. There are no specific rules for accommodating an experiment to spatial heterogeneity. Dutilleul (1993) points out that the experimenter's knowledge about the experimental material is an important source of information during the design of the experiment, and he recommends that: 1) the method of randomised (complete or incomplete) blocks is used to overcome the vagaries of assigning treatments to experimental units; 2) that a completely randomised design should only be employed in experiments where the experimental field is homogeneous at large scale and the number of experimental units is not too small; and 3) that a Latin square design is appropriate where experimental fields are hetereogeneous in two directions.

Ecologists and statisticians agree that well designed experiments rely on three basic concepts: replication; blocking; and randomisation. Replication is obtained by the repeated application of the set of treatments to all experimental units. Replication allows estimation of treatment effects by averaging over the underlying variability in the experimental units. Blocking helps control natural heterogeneity by assigning experimental units to relatively homogeneous groups. Blocks may consist of experimental units that are spatially close, or that are related in some way. For example, a field with a shallow centre drainage may be blocked into those areas which are higher and drier, and into those which are lower and wetter. Randomisation is the process of assigning treatments randomly to experimental units. It helps to provide unbiased estimates of parameters.

Ecological questions often concern how multiple components might respond to some change in the environment or might differ among groups. Often the interest is centered on the interaction among these components and on how the interactions might change as the environment changes. Missing data points will not be a problem if a general linear model is employed. The results of MANOVA (multivariate analysis) are reliable provided that the smallest cell is not less than 50% the size of the largest cell (Scheiner 1993). The basics of MANOVA are similar to those of ANOVA, except that centroids, rather than the means of groups, are compared. A centroid is a multivariate mean, the centre of a multidimensional distribution. The procedures for specifying a model and response variables are the same as for ANOVA, but the MANOVA statement is added. The test for significant differences, like this test in ANOVA, is based on examining the variation among groups to see if it is larger than would be expected by chance given the variation within groups. The standard F statistic is used in this procedure. The actual formula is based on the ratio of the among-group sums-of-squares / cross-product (SSCP) matrix, divided by the pooled within-group error matrix. Four statistics for the test of significant differences among the groups are used: Wilk's lambda, Pillai's trace, Lawley-Hotelling's trace and Roy's (Minitab Reference Manual 1994) . Often, the statisical conclusions about whether the groups differ are identical for all four measures.

6.1.2 Materials and Methods

A plot of approximately 1000 m^2 at Bath University Field Station, Bathampton (grid reference ST 774 666 Sheet 172), was prepared and sown with a low growing grass mixture (A4, British Seed Houses, Avonmouth, Bristol), which is recommended for sowing with local flora. From the results of the investigation of germination of achenes in the field (chapter 3, section 3.2.3) it has been decided that plants for this field growth experiment should be germinated in the greenhouse and grown in pots to the four true leaf stage before hardening off and subsequent transplanting into position to ensure the best possible chance of survivorship during the early stages of growth.

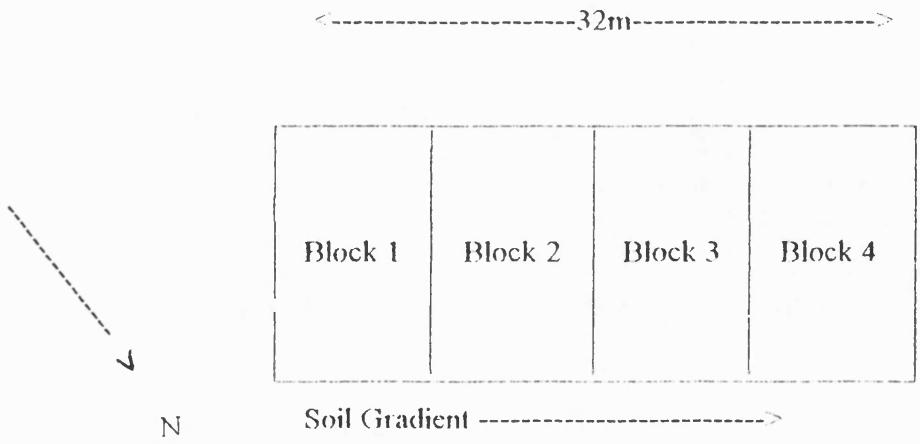
The *Taraxacum* plants for this experiment were selected from a single capitulum from each of five clones (from two of the original locations): M1,M2,W1,W3 and W5. (The reason for this selection was that only these clones had produced achenes by the time it was necessary to germinate material for the field trial.) For each capitulum, the achenes were individually weighed and then grouped into four weight classes. The classes were comparative, as the weight range of achenes per capitulum is not identical. For each clone, the classes were the 40 lighest achenes to germinate, the heaviest 40 achenes to germinate and two intermediate classes each of 40 achenes. These can be described approximately as <0.5mg, 0.5-0.6mg, 0.61-0.7mg and >0.7mg (Table 29).

Table 29 The achene weight range for each clone used in the field experiment.

Clone	Achene weight range in mg			
	Class 1	Class 2	Class 3	Class 4
M1	0.5898-0.6882	0.6926-0.7387	0.7420-0.7675	0.7700-0.8313
M2	0.3550-0.4714	0.5249-0.5894	0.6203-0.6604	0.6854-0.8052
W1	0.3556-0.5492	0.6617-0.7462	0.8684-0.8975	0.9386-1.0695
W3	0.4022-0.5068	0.5376-0.5815	0.5995-0.6188	0.6336-0.7108
W5	0.3663-0.5014	0.5258-0.5725	0.6025-0.6565	0.7046-0.8022

These achenes, along with extras used to provide plants for a sacrificial row which was established around the plot, were germinated under the mist unit as previously described. Seedlings at the two true leaf stage were potted into $3\frac{1}{2}$ inch pots containing M2 Levington compost and left to overwinter in a cold greenhouse. They were not repotted into larger pots, but were left in the small pots so that a good root system could establish. Having a well developed root system means that the plants suffer less of a growth check when planted out. For this experiment, there was a total of 640 plants, comprising 5 clones x 4 weight classes x 8 replicates x 4 blocks. Field planting commenced in February 1993 after the grass was cut. The experiment was laid out in a randomised block design, with the plants spaced at 1 metre intervals. The design for this experiment was dictated by the land available. The lower part of the plot slopes gently north-west down towards the River Avon and there is an ash gradient running across the plot north-east to south-west, due to there having been an ash tip located in the past at the extreme south west boundary. The blocks were designed to run across the ash gradient (Figure 18 and Plate 11).

Figure 18 Experimental design of the field experiment



The plot was surrounded by a "sacrificial" or "guard" row of plants sown 1m apart, so that every plant in the experiment was surrounded by 4 other plants each 1m away. The whole plot was then surrounded by a rabbit-proof electric fence. Four plants from each clone (two from the lightest weight size class and two from

Plate 11

Field experiment looking north-west across the plot. Grass has been mown between the plants. Plants in the foreground are in the environmental sensitivity experiment.

the heaviest weight class) were randomly selected from blocks 2 and 4 as a sub-set for more intensive study. Some plants died in the period immediately following transplanting. These spaces were filled with extra plants grown for this purpose so that all plants were surrounded by 4 others at the start of the experiment.

The measurements taken during the course of the experiment were:

a) Length of flowering period for each plant in the experiment for the two seasons that the experiment ran.

b) Mean rosette diameter of every plant at the beginning and end of each growing season.

c) Root crown diameter and dry weight of each plant at the end of the experiment.

In addition, total number of leaves and the effective leaf area were monitored every fortnight throughout the two growing seasons for the sub-set of 40 plants. Effective leaf area was measured using a clear perspex sheet containing a grid of 1cm squares. This was held over the plant, with care being taken not to flatten the foliage, and the foliage area was assessed. To ensure that this provided an accurate measurement, the plants were regularly re-assessed in random order on the same day as the recorded measurements were taken, and the two values were compared. Very similar results were obtained each time this was performed, with an error of no more than $\pm 2cm^2$.

6.1.3 Flowering period.

Results

An initial objective was to record the number of capitula produced by each plant. This objective could not be met because of large scale damage to the plants and capitula by rabbits, birds and field slugs (*Derocerus reticulatum*).

In block I, three of the original 160 seedlings planted failed to establish, 87

(55%) flowered in the first year and 49 (31%) flowered in the second year with 28 (18%) of the plants flowering in both years. In block II, five plants failed to establish, 90 (58%) flowered in the first year, 70 (45%) in the second year, and 43 (28%) of the plants flowered in both years. In block III, five plants failed to establish, 100 (65%) flowered in the first year and 79 (51%) flowered in the second year and 20 (31%) flowered in both years. Four plants failed to establish in block IV, 119 (76%) flowered in the first year and 124 (79%) flowered in the second year and 90 (58%) flowered in both years.

An ANOVA was performed on the number of plants that flowered per weight class per clone per block (for each year). The main effects were included as were the first and second order interactions. As none of the latter were significant, it was not necessary to include third order interactions (i.e. year*clone*class*block). The final analysis is presented below in Table 30.

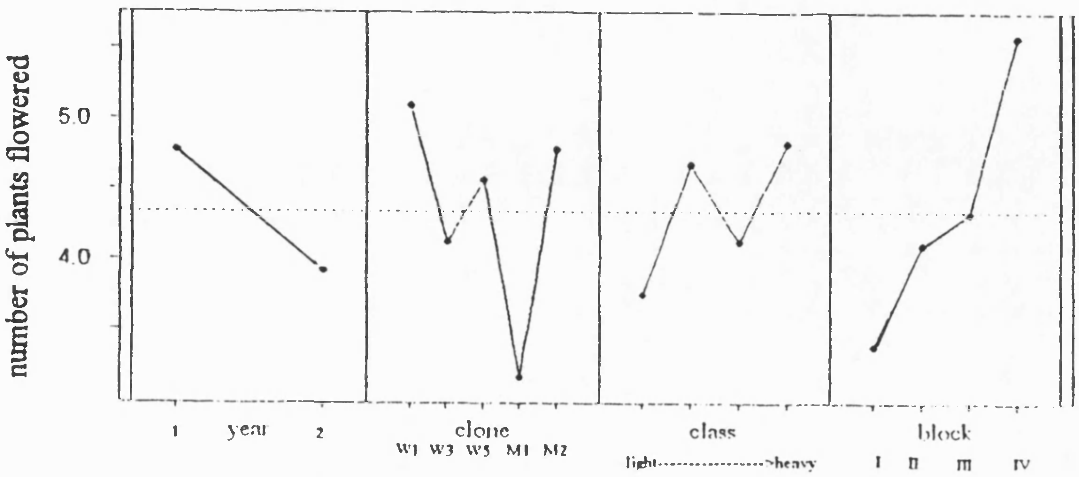
Table 30 Analysis of Variance table for number of plants that flowered.

Source	DF	SS	MS	F	P
year	1	29.756	29.756	15.58	0.000
clone	4	72.312	18.078	9.47	0.000
class	3	29.669	9.890	5.18	0.004
block	3	100.569	33.523	17.56	0.000
year*clone	4	31.837	7.959	4.17	0.007
year*class	3	0.119	0.040	0.02	0.996
year*block	3	39.219	13.073	6.85	0.001
clone*class	12	37.237	3.103	1.63	0.128
clone*block	12	12.837	1.070	0.56	0.859
class*block	9	9.756	1.084	0.57	0.814
year*clone*class	12	36.912	3.076	1.61	0.132
year*clone*block	12	20.312	1.693	0.89	0.568
year*class*block	9	12.606	1.401	0.73	0.676
clone*class*block	36	72.213	2.006	1.05	0.442
Error	36	68.738	1.909		
Total	159	574.094			

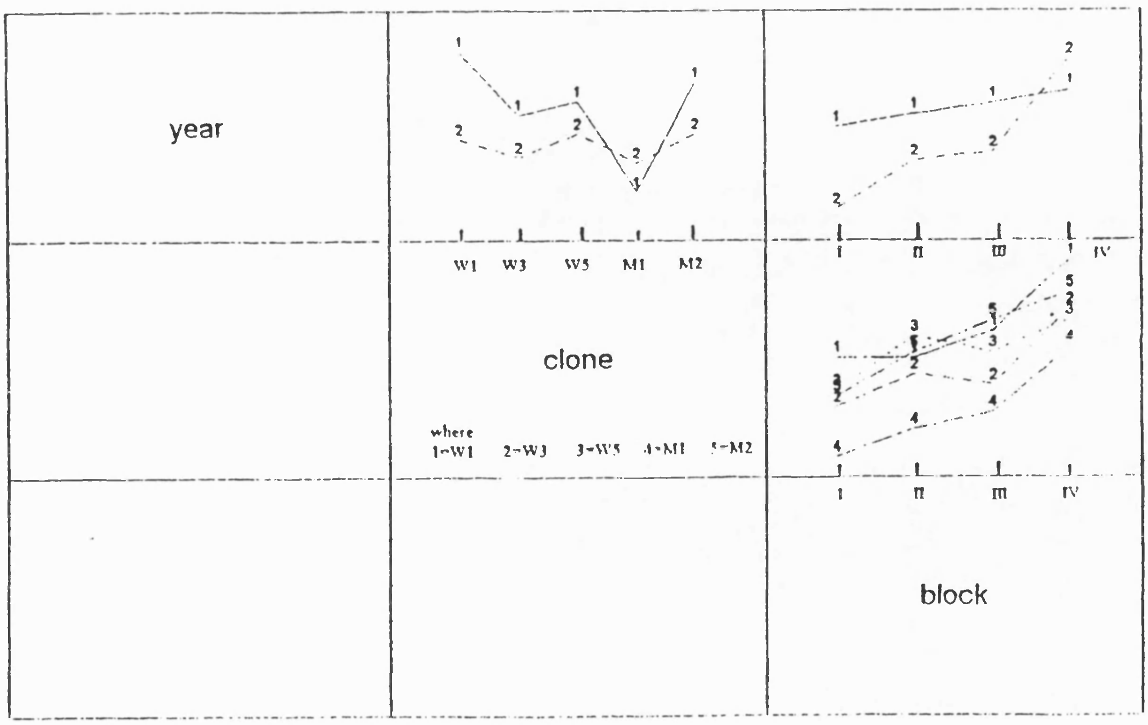
Plots, presented in Figure 19, show both main and interaction effects for those terms shown to be significant (at $p<0.05$). The analysis shows that year, clone, class, block and the interactions between year and clone and year and block are all highly significant ($p<0.01$). The main effects show that in year 1 just over 4 plants out of 8 (for each weight class, per clone per block) flowered. In year 2 this fell to

Figure 19 Main and interaction effects for number of plants that flowered in year 1 and year 2

(a) Main effects for field experiment data



(b) Interaction effects for field experiment data



just below 4. Clone M1 performed least well, and W1 produced the greatest number of flowering individuals. The heaviest weight class also produced more flowering plants than the lightest which produced the least. There was a trend for more plants to flower in block IV than in block I. Of the interaction effects, all clones produced more plants that flowered in year 1 except for M1. There was a steady increase in the number of flowering plants across the field from block I to block IV in both years, but more markedly so in year 2. All clones performed better in block IV than in block I, although it was not necessarily a steady increase in the number of plants that flowered across the field plot. For example, flowering in clone W3 was similar in blocks I, II and III, but much higher in block IV than in the other blocks.

Discussion

The over-riding factor affecting these results is the 'block' effect which was less noticeable in year 1 than in year 2, but was nevertheless still apparent. This effect may be due to the ash gradient which affected the growth of the sward. What is not known is whether the ash affects *Taraxacum* growth directly, or indirectly through affecting growth of the sward.

Although two clones (M1, and to a lesser extent W3) produced less than the average number of flowering plants per group (i.e. weight class per block) all clones were affected in a similar way by the environment. Plants produced from heavier achenes were more likely to flower than plants grown from lighter achenes, and plants growing in shorter vegetation (eg block IV) were more likely to flower than plants growing in longer vegetation (eg block I). The flowering of plants, and subsequent capitula and achene production will be looked at in more detail in the section concerned with the intensive study of the sub-set of plants.

6.1.4 Mean rosette diameter.

Results

The whole field experiment was assessed three times: the beginning and end of the first season and the start of the second season. At the end of the second season, the plants were dug up and both root crown diameter and dry weight were measured. (These latter data will be analysed in the next section: 6.1.5).

There were missing values in all assessments, particularly in the third (after over-wintering). Because of this, a General Linear Model had to be applied to the Analysis of Variance. This Model adjusts for unequal observations within groups. As it was known from the previous data set that block had a significant influence, it was only included as a main effect along with clone and weight class. One first order interaction was included, that of clone*class. Each assessment was analysed independently and is given in Table 31 (a)-(c).

Table 31

(a) Analysis of variance table for first rosette diameter assessment.

Source	DF	Seq SS	Adj SS	Adj MS	F	P
block	3	70.663	71.560	23.853	4.21	0.006
clone	4	54.198	51.654	12.913	2.28	0.060
class	3	16.281	13.904	4.635	0.82	0.484
clone*class	12	81.838	81.838	6.820	1.20	0.277
Error	417	2360.208	2360.208	5.660		
Total	439	2583.188				

The block effect is the most significant ($p<0.01$). The clone effect is bordering on significance at $p = 0.06$. There is no significant class or interaction effect.

(b) Analysis of variance table for second assessment of rosette diameter. (End of first flowering season)

Source	DF	Seq SS	Adj SS	Adj MS	F	P
block	3	424.10	381.44	127.15	3.66	0.013
clone	4	473.52	438.46	109.62	3.16	0.014
class	3	347.22	346.66	115.55	3.33	0.020
clone*class	12	295.67	295.67	24.64	0.71	0.742
Error	417	14472.60	14472.60	34.71		
Total	439	16013.12				

This analysis shows that block, clone and weight class are all significant ($p<0.05$). There is no significant interaction effect.

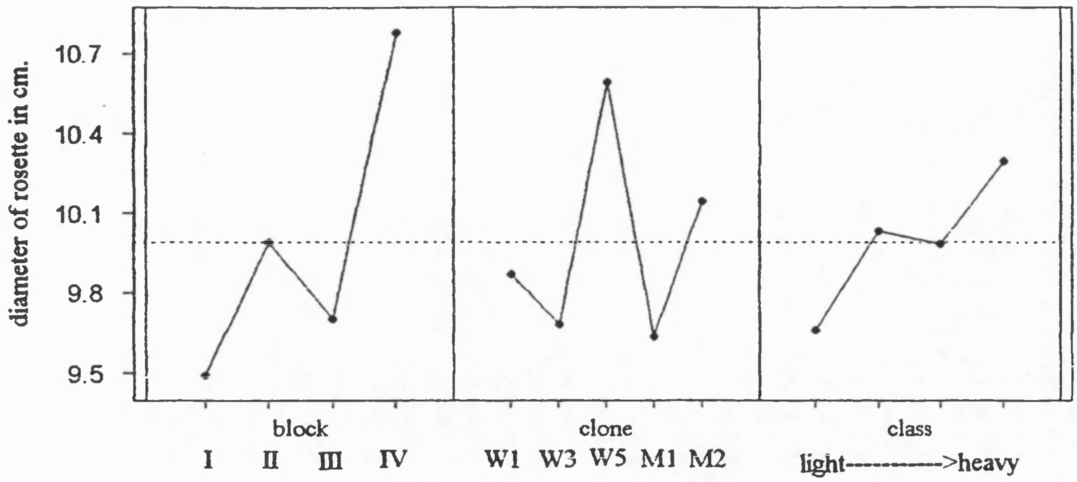
(c) Analysis of variance table for rosette diameter assessment at the start of the second season.

Source	DF	Seq SS	Adj SS	Adj MS	F	P
block	3	839.69	843.03	281.01	6.11	0.000
clone	4	337.94	322.82	80.70	1.75	0.137
class	3	145.22	125.50	41.83	0.91	0.436
clone*class	12	878.28	878.28	73.19	1.59	0.091
Error	417	19176.91	19176.91	45.99		
Total	439	21378.04				

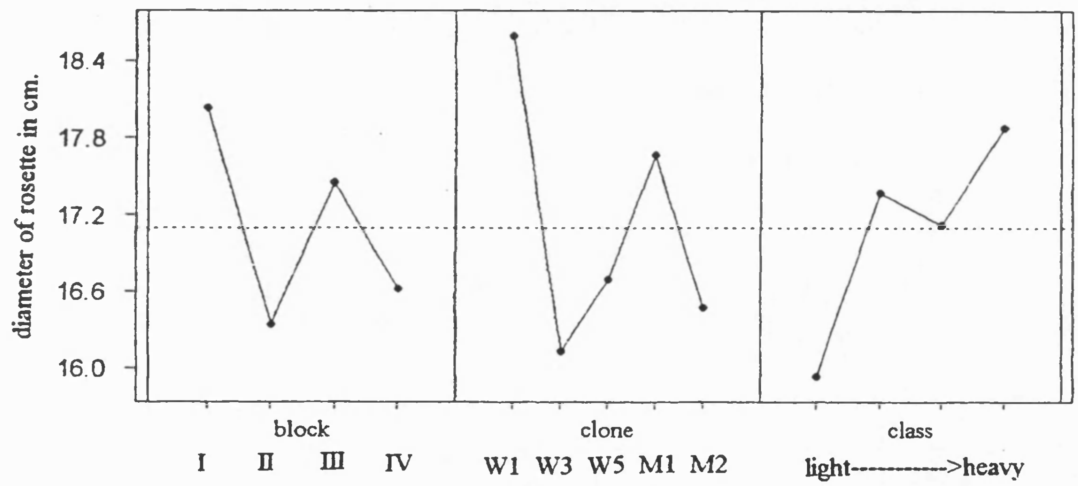
The only significant factor was the block effect. Figure 20 (a) (b) and (c) show the main effects plots for each assessment. Figure 21 shows the mean rosette diameter for all plants in blocks I and IV. The plants are grouped into weight classes for each clone and the mean diameter clustered for each of the three assessments. Standard error bars are given for each mean. These two blocks were selected for further analysis because they showed the most extreme block effects and were therefore most likely to show any differences that may have been present as a result of environmental conditions. (NB the large value for W3 block IV is due to the influence of one very large rosette.) Comparison of the graphs for assessment 1 shows slight differences between weight classes, but these are not significant (refer to ANOVA tables above). Differences also occur between the

Figure 20

(a) Main effects plots for initial assessment.



(b) Main effects plots for second assessment.



(c) Main effects plots for third assessment.

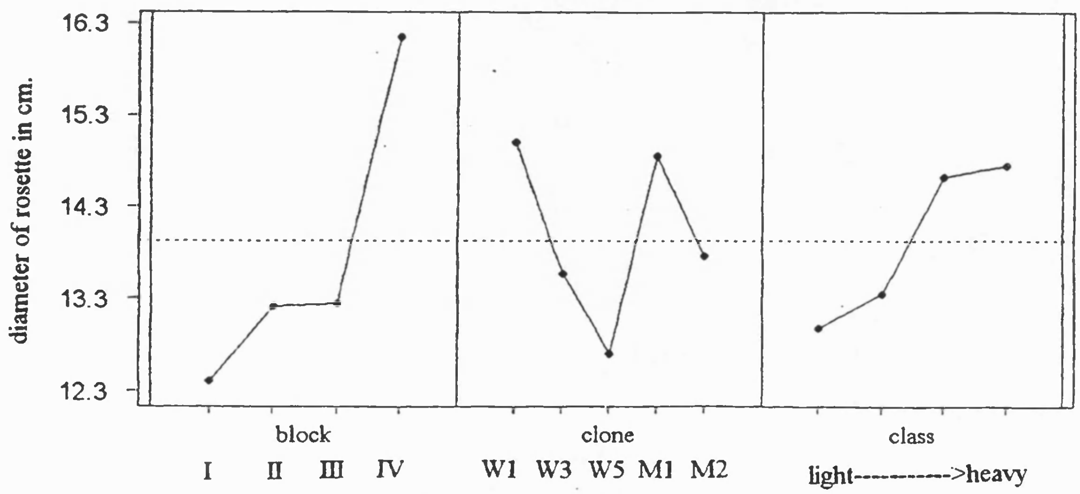
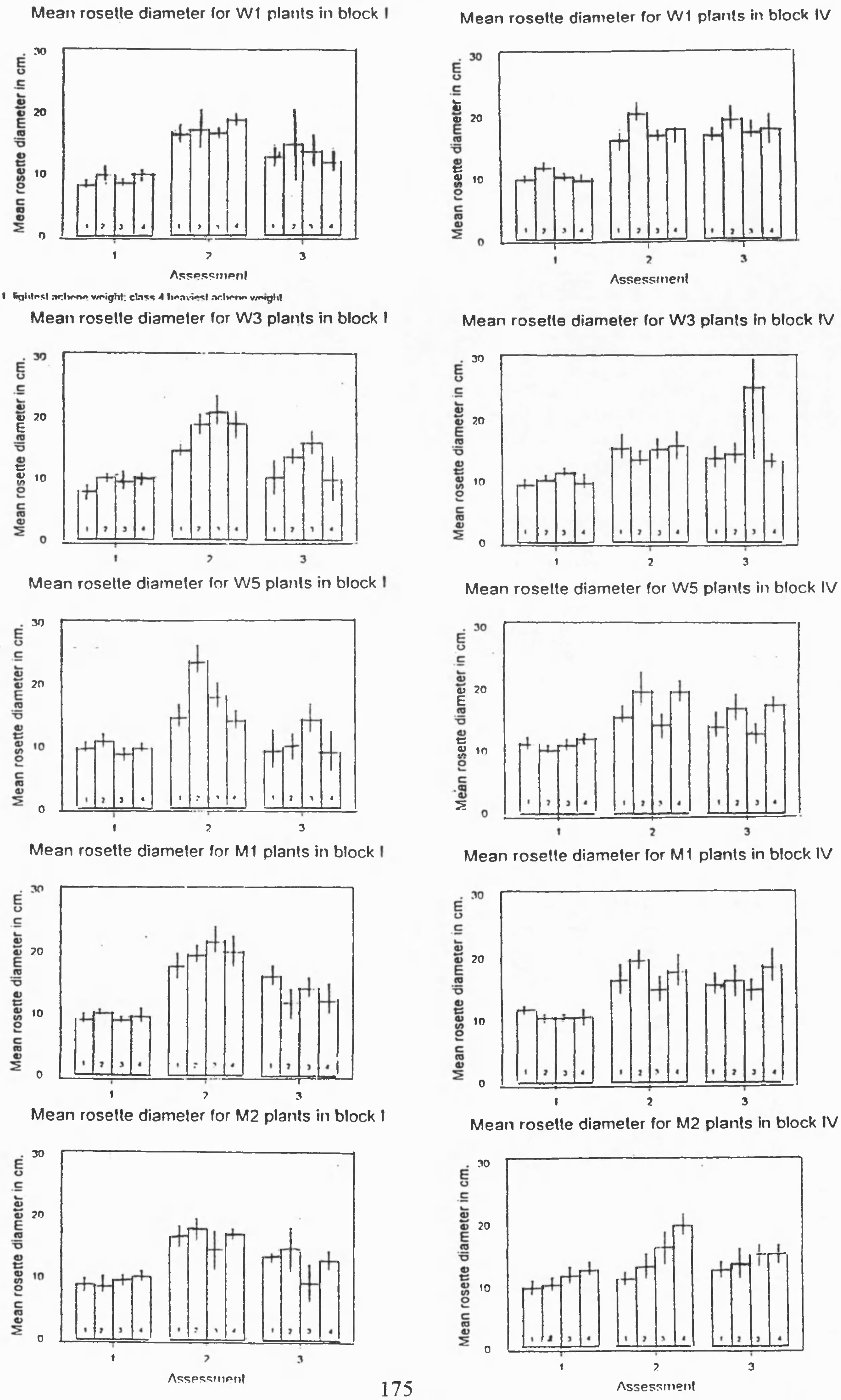


Figure 21

Mean rosette diameter of all plants in blocks I and IV

Standard error bars are shown at the top of each mean value.



two blocks, but again these are not significant. Differences between clones are shown in the ANOVA but not shown in these figures. However these differences may be from blocks II and III which are not in this sample. For the second assessment, weight class, clone and block differences are detected. Fot the third assessment, block differences are found, with plants in block IV producing larger rosettes than the corresponding clone and weight class groups in block I. This parallels the findings detected by the ANOVA.

Discussion

Plants had a greater mean diameter in block IV at the first assessment, which was conducted about 1 month after the plants were planted. By the end of the first season plants in block I had the greatest mean diameter. After over-wintering, when rosettes contract, (Grime, Hodgson and Hunt 1988), block IV showed the greatest mean diameter at the third assessment. By this assessment, predation of plants was high, especially in block I. Indeed, some plants in this block had had all of their foliage removed, whilst others had had their leaves shortened. Each plant in this block appeared to have its own collection of field slugs.

W5 had the greatest mean diameter at the start of the experiment, but W1 had the largest mean diameter in the next assessment, followed by M1. However, by the third assessment W1 is not significantly different from M1. Both of these clones had above the average mean diameter fro the second and third assessments. It appears that W5 may have been quick to establish in the field, but that W1 and M1 were the most competitive clones in the grassland environment.

In all three assessments plants grown from heavier achenes tended to be larger in diameter than plants grown from light achenes. In 70% of the clonal assessments (i.e.21 out of 30 'clusters') shown in Figure 21 plants grown from heavier achenes do in fact produce a larger mean rosette diameter than plants grown from the lightest achene class. By the third assessment, the weight class factor had lost significance. This indicates that a plant from a heavy achene has an advantage over one grown from a light achene over the first year of growth, but that this advantage disappears during the second year of growth. Thus greater achene weight provides a short term advantage that may be crucial during the period of establishment.

6.1.5 Root crown diameter and dry weight correlation

Results

At the end of the experiment (October/November 1994), every plant was dug up. The root crown diameter of each plant was measured several times and an average value was recorded. The foliage was then removed at the root crown and was dried in an oven at 80°C to a constant dry weight. The Pearson's correlation coefficient between root crown diameter and the dry weight of foliage was 0.627. A general linear model was applied to the analysis of variance because there were missing data points. Root crown diameter and dry weight were analysed separately. Block, weight class and clone were the main effects and the first order interactions block*class, block*clone and clone*class were included. For both of the responses, only the block effect was significant ($p<0.01$). However, class*clone was significant ($p<0.05$) for dry weight. Table 32 (a) gives the ANOVA table for root crown diameter and (b) the ANOVA table for dry weight.

Table 32

(a) Analysis of variance table for root crown diameter

Source	DF	Seq SS	Adj SS	Adj MS	F	P
block	3	455.40	494.68	164.89	4.59	0.004
class	3	20.15	128.19	42.73	1.19	0.315
clone	4	76.50	62.51	15.63	0.43	0.784
block*class	9	662.29	585.89	65.10	1.81	0.067
block*clone	12	328.68	354.78	29.56	0.82	0.628
class*clone	12	676.56	676.56	56.38	1.57	0.101
Error	265	9529.79	9529.79	35.96		
Total	308	11749.37				

(b) Analysis of variance table for dry weight

Source	DF	Seq SS	Adj SS	Adj MS	F	P
block	3	20.495	16.729	5.576	3.89	0.010
class	3	6.180	4.004	1.335	0.93	0.426
clone	4	4.083	3.188	0.797	0.56	0.695
block*class	9	9.750	7.283	0.809	0.56	0.826
block*clone	12	9.245	9.223	0.769	0.54	0.890
class*clone	12	32.762	32.762	2.730	1.90	0.034
Error	265	380.129	380.129	1.434		
Total	308	462.645				

Discussion

Root crown diameter and dry weight of foliage are positively associated, so it may be assumed that a large rosette is produced by a plant with a large root crown.

This assessment, which was made at the end of the experiment, supports the conclusion made in the previous section that after two seasons growth all plants behave similarly given the same environmental conditions. This is true for both class and clone differences. Any benefits gained from having germinated from a heavier achene appear to be minimal by the end of the second growing season. In this experiment, it may be said that there is no effect seen at the end of the two seasons, but differences are seen over (ie during) the two seasons. This is supported by the results of the non-destructive harvesting experiment reported in chapter 4, section 4.2 where both clonal and weight class differences were detected during the 77 days duration of the experiment.

6.1.6 Intensive study of subsets of plants

Results

A general linear model was employed because of missing values, but on this occasion it was not only applied to an analysis of variance, but also to multivariate analysis (Scheiner 1993).

Year 1 assessment.

During the first year, assessments at fortnightly intervals were recorded from April-September 1993. The number of leaves and the effective leaf area were measured. The correlation coefficient for these measurements was 0.597. Tables 33 and 34 give the ANOVA results for the number of leaves and effective leaf area respectively.

Table 33 Analysis of variance table for number of leaves.

Source	DF	Seq SS	Adj SS	Adj MS	F	P
clone	4	481.08	376.87	94.22	6.43	0.000
size	1	1100.26	1144.24	1144.24	78.13	0.000
time	11	1543.31	1425.97	129.63	8.85	0.000
block	1	671.20	683.36	683.36	46.66	0.000
clone*size	4	386.67	389.85	97.46	6.65	0.000
clone*time	44	312.06	282.86	6.43	0.44	0.999
size*time	11	139.47	142.36	12.94	0.88	0.557
clone*size*time	44	294.20	294.20	6.69	0.46	0.999
Error	344	5038.30	5038.30	14.65		
Total	464	9966.55				

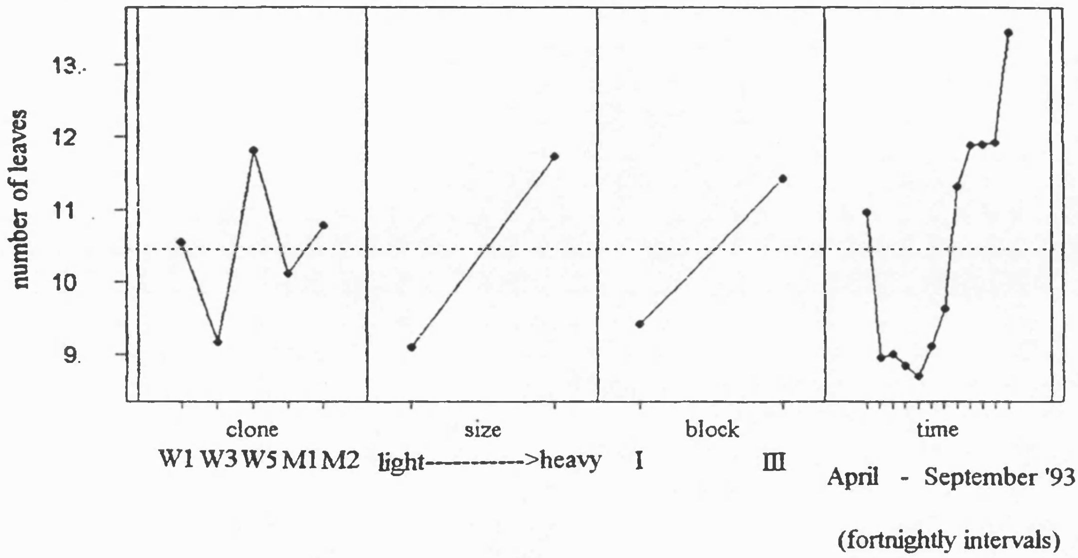
The main effects of clone, size (weight class), time and block were all highly significant ($p<0.001$) as was the first order interaction of clone*size ($p<0.001$).

Table 34 Analysis of variance for effective leaf area.

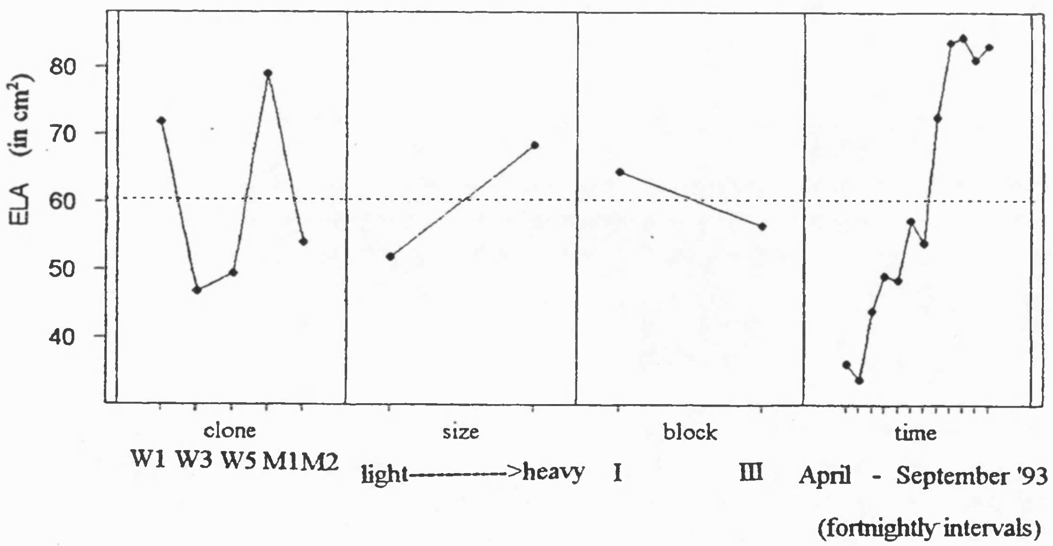
Source	DF	Seq SS	Adj SS	Adj MS	F	P
clone	4	76800	75147	18787	10.34	0.000
size	1	33952	30618	30618	16.86	0.000
time	11	157290	149898	13627	7.50	0.000
block	1	6633	6627	6627	3.65	0.057
clone*size	4	25428	25492	6373	3.51	0.008
clone*time	44	42736	39973	908	0.50	0.997
size*time	11	10502	10502	955	0.53	0.886
clone*size*time	44	23115	23115	525	0.29	1.000
Error	344	624829	624829	1816		
Total	464	1001285				

Figure 22 Main and interaction effects for number of leaves and ELA in year 1.

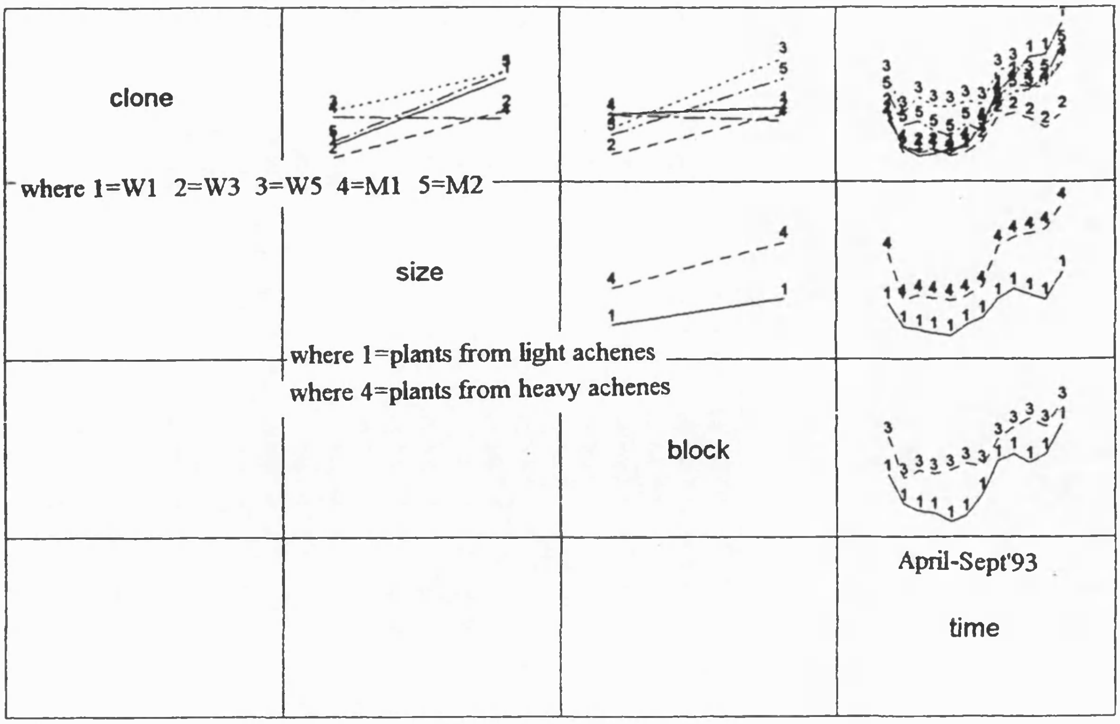
(a) Main effects plots for number of leaves



(b) Main effects plots for effective leaf area



(c) Interaction plots for number of leaves



(d) Interaction plots for effective leaf area

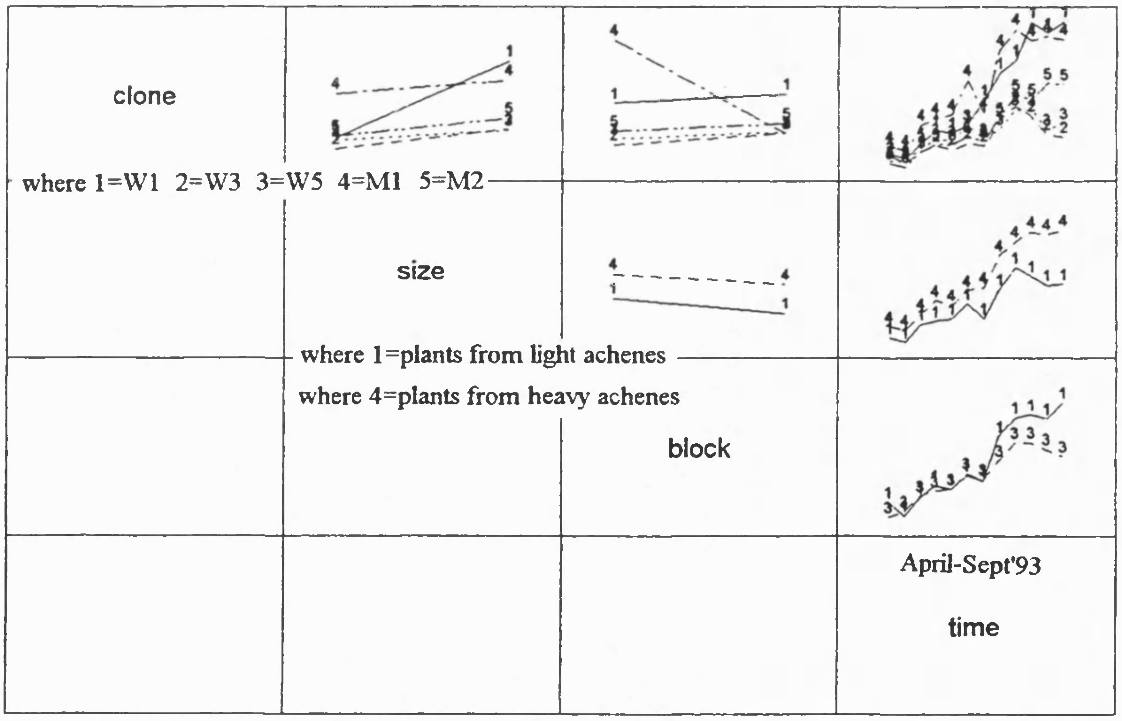


Table 34 Results of Manova for a) year 1 and b) year 2

(a)

MANOVA for clone s = 2 m = 0.5 n = 170.5

CRITERION	TEST STATISTIC	F	DF	P
Wilk's	0.74003	13.930	(8. 686)	0.000
Lawley-Hotelling	0.33595	14.362	(8. 684)	0.000
Pillai's	0.27133	13.499	(8. 688)	0.000
Roy's	0.28140			

MANOVA for size s = 1 m = 0.0 n = 170.5

CRITERION	TEST STATISTIC	F	DF	P
Wilk's	0.80676	41.078	(2. 343)	0.000
Lawley-Hotelling	0.23952	41.078	(2. 343)	0.000
Pillai's	0.19324	41.078	(2. 343)	0.000
Roy's	0.23952			

MANOVA for time s = 2 m = 4.0 n = 170.5

CRITERION	TEST STATISTIC	F	DF	P
Wilk's	0.67314	6.824	(22. 686)	0.000
Lawley-Hotelling	0.44160	6.865	(22. 684)	0.000
Pillai's	0.35645	6.782	(22. 688)	0.000
Roy's	0.28999			

MANOVA for block s = 1 m = 0.0 n = 170.5

CRITERION	TEST STATISTIC	F	DF	P
Wilk's	0.75025	57.092	(2. 343)	0.000
Lawley-Hotelling	0.33290	57.092	(2. 343)	0.000
Pillai's	0.24975	57.092	(2. 343)	0.000
Roy's	0.33290			

MANOVA for clone*size s = 2 m = 0.5 n = 170.5

CRITERION	TEST STATISTIC	F	DF	P
Wilk's	0.87076	6.144	(8. 686)	0.000
Lawley-Hotelling	0.14421	6.165	(8. 684)	0.000
Pillai's	0.13292	6.122	(8. 688)	0.000

(b)

MANOVA for class s = 1 m = 0.0 n = 78.5

CRITERION	TEST STATISTIC	F	DF	P
Wilk's	0.99800	0.160	(2. 159)	0.853
Lawley-Hotelling	0.00201	0.160	(2. 159)	0.853
Pillai's	0.00200	0.160	(2. 159)	0.853
Roy's	0.00201			

MANOVA for time s = 2 m = 3.0 n = 78.5

CRITERION	TEST STATISTIC	F	DF	P
Wilk's	0.74763	2.765	(18. 318)	0.000
Lawley-Hotelling	0.33139	2.909	(18. 316)	0.000
Pillai's	0.25698	2.621	(18. 320)	0.000
Roy's	0.31159			

MANOVA for block s = 1 m = 0.0 n = 78.5

CRITERION	TEST STATISTIC	F	DF	P
Wilk's	0.81466	18.087	(2. 159)	0.000
Lawley-Hotelling	0.22751	18.087	(2. 159)	0.000
Pillai's	0.18534	18.087	(2. 159)	0.000
Roy's	0.22751			

MANOVA for clone*class s = 2 m = 0.5 n = 78.5

CRITERION	TEST STATISTIC	F	DF	P
Wilk's	0.83190	3.832	(8. 318)	0.000
Lawley-Hotelling	0.19370	3.826	(8. 316)	0.000
Pillai's	0.17507	3.837	(8. 320)	0.000
Roy's	0.12862			

Clone, size, time, and clone*size effects were again highly significant ($p<0.01$). Block effects were close to significance ($p = 0.057$).

For the interaction between the two variables (number of leaves and effective leaf area), the MANOVA identified significant effects for clone, size, time, block and clone*size. Comparing the results from the ANOVA and MANOVA, it can be concluded that the number of leaves has the greatest influence (see Figure 22 (a), (b), (c) and (d)). The MANOVA results for both year 1 and year 2 are given in Table 35 (a) and (b) respectively.

Year 2 assessment

The assessments were again made at fortnightly intervals, this time running for 5 months from May-September 1994. The Pearson coefficient for the two variables was 0.616. Table 36 and 37 give the ANOVA results for number of leaves and effective leaf area repectively.

Table 36 Analysis of variance for number of leaves.

Source	DF	Seq SS	Adj SS	Adj MS	F	P
clone	4	1251.79	1287.15	321.79	6.72	0.000
class	1	787.18	779.92	779.92	16.28	0.000
block	1	503.96	309.62	309.62	6.46	0.012
time	9	844.70	817.63	90.85	1.90	0.054
clone*class	4	735.26	780.28	195.07	4.07	0.003
clone*time	36	615.35	623.22	17.31	0.36	1.000
class*time	9	90.54	90.54	10.06	0.21	0.993
Error	196	9390.45	9390.45	47.91		
Total	260	14219.23				

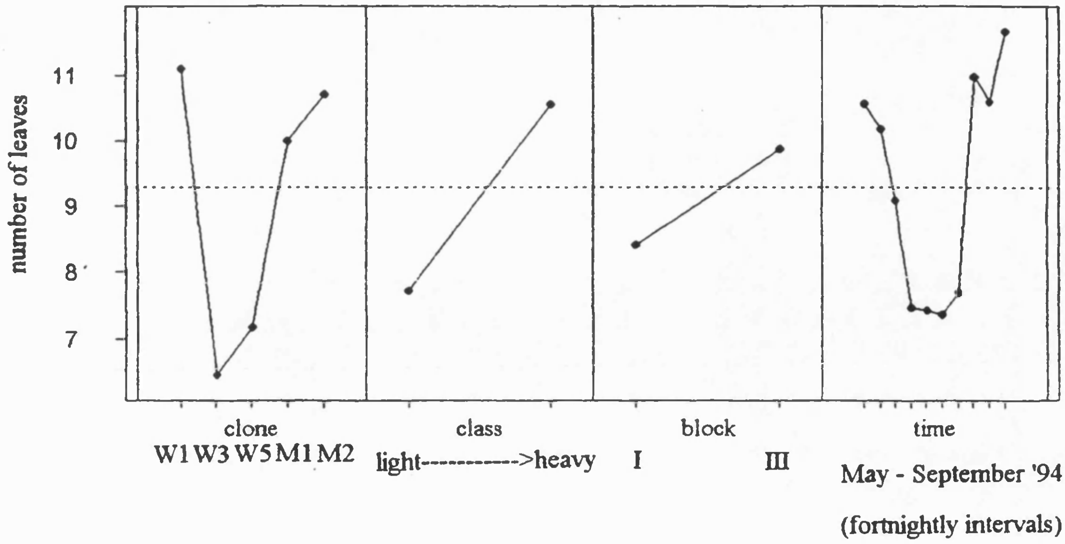
Clone, (weight) class, and clone*class were all significant ($p<0.01$), with block significant at $p<0.05$. Time was not quite significant at the $p<0.05$ level.

Table 37 Analysis of variance for effective leaf area.

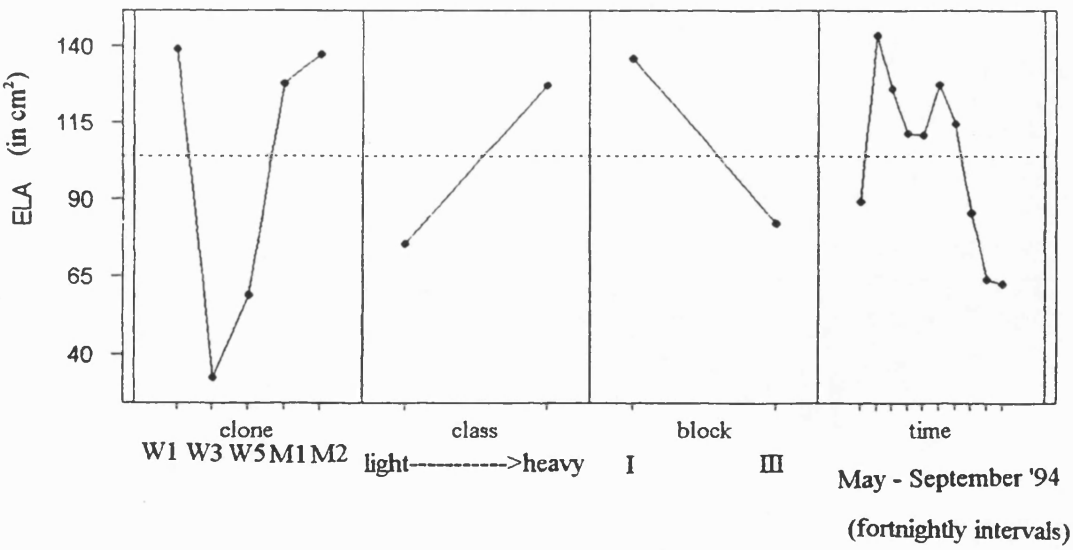
Source	DF	Seq SS	Adj SS	Adj MS	F	P
clone	4	466250	379458	94865	6.50	0.000
class	1	179260	123551	123551	8.46	0.004
block	1	89717	105453	105453	7.22	0.008
time	9	208888	126554	14062	0.96	0.472
clone*class	4	391006	403109	100777	6.90	0.000
clone*time	36	210264	219276	6091	0.42	0.999
class*time	9	38120	38120	4236	0.29	0.977
Error	196	2862161	2862161	14603		
Total	260	4445666				

Figure 23 Main and interaction effects for number of leaves and ELA in year 2.

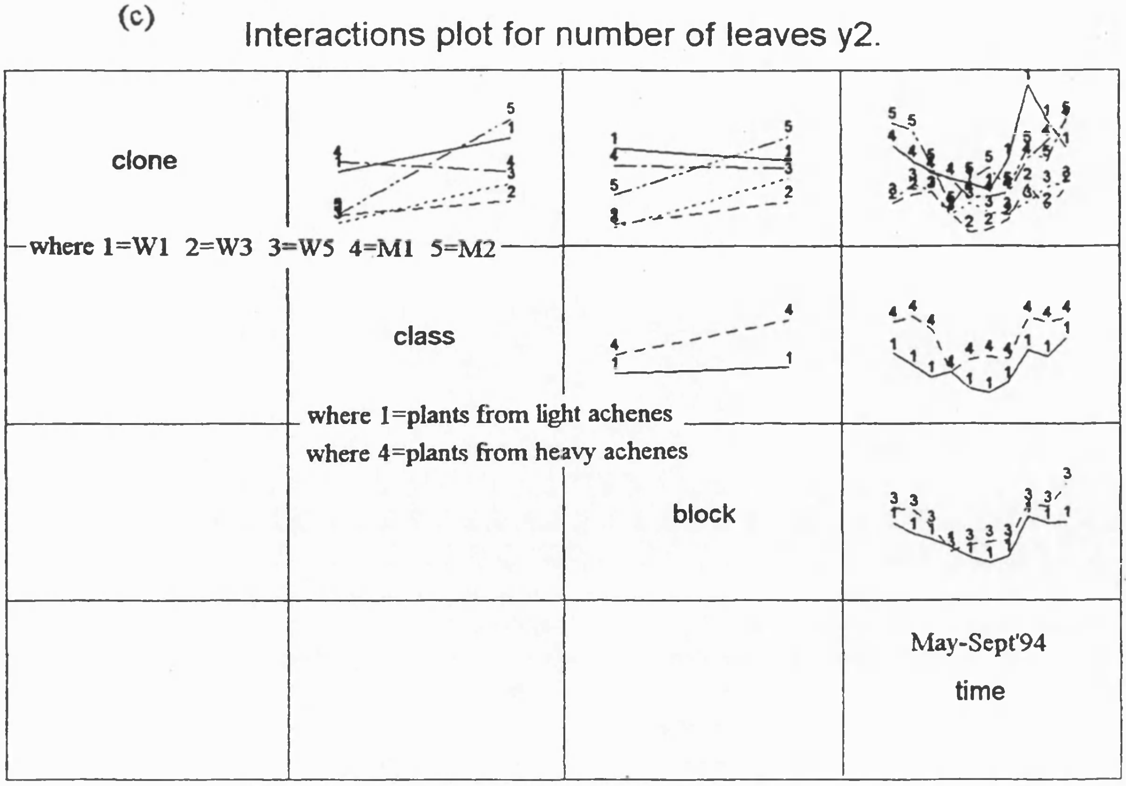
(a) Main effects plots for number of leaves year 2



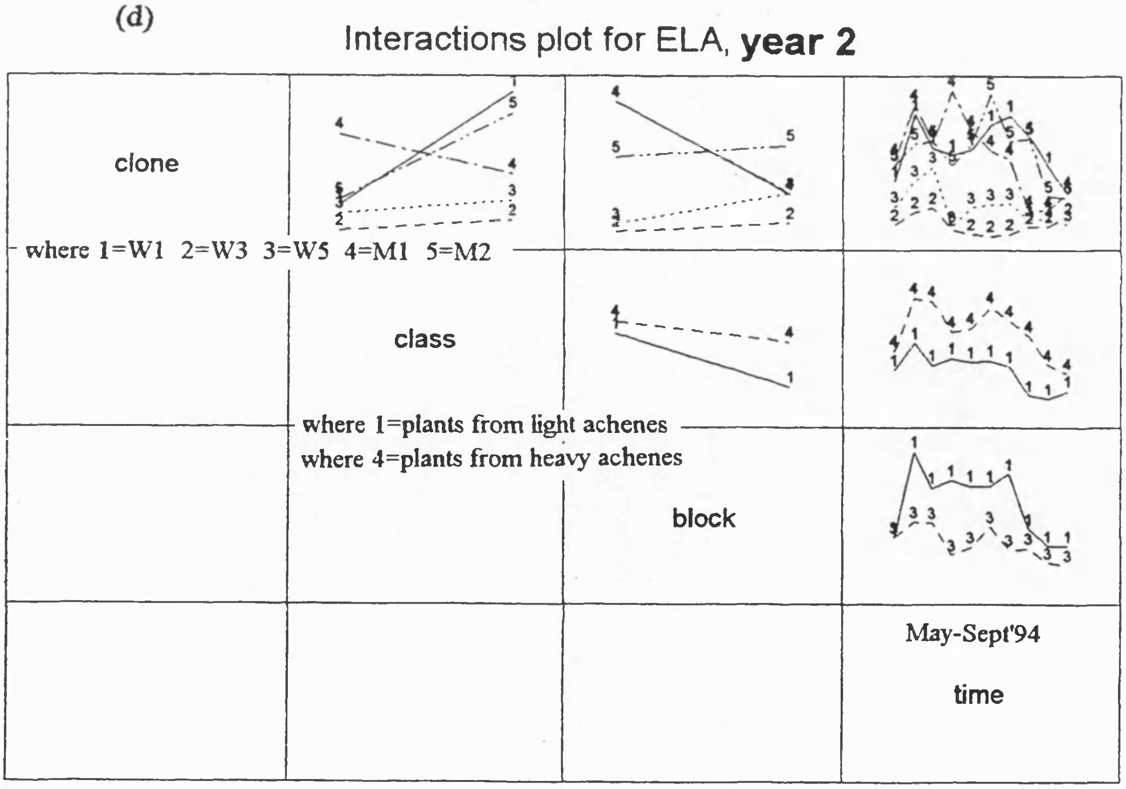
(b) Main effects plots for effective leaf area, **year 2**



(c)


Interactions plot for number of leaves y2.
clone
where 1=W1 2=W3 3=W5 4=M1 5=M2
class
where 1=plants from light achenes
where 4=plants from heavy achenes
block
May-Sept'94
time

(d)


Interactions plot for ELA, year 2
clone
where 1=W1 2=W3 3=W5 4=M1 5=M2
class
where 1=plants from light achenes
where 4=plants from heavy achenes
block
May-Sept'94
time

Clone, class, block, clone*class were all highly significant ($p<0.01$). The MANOVA (Table 29 (b)) showed that the interaction between the two variables was significant for time, block and clone*class. The ELA (effective leaf area) was the dominant factor in the interaction for the significance found at the block level. Time was not a significant factor in either ANOVA. However, the main effects plots (Figure 23 (a) and (b)) show a discrepancy between the two variables. Initially, the number of leaves falls and ELA rises and then towards the end of the period number of leaves rises and ELA falls. Figure 23 (c) and (d) show the interaction plots in year 2.

As reported in the previous chapter, capitula and achene production over the two seasons for the sub-set of plants has been assessed. The results are shown in figure 24 for capitula production and figure 25 for achene production.

Discussion

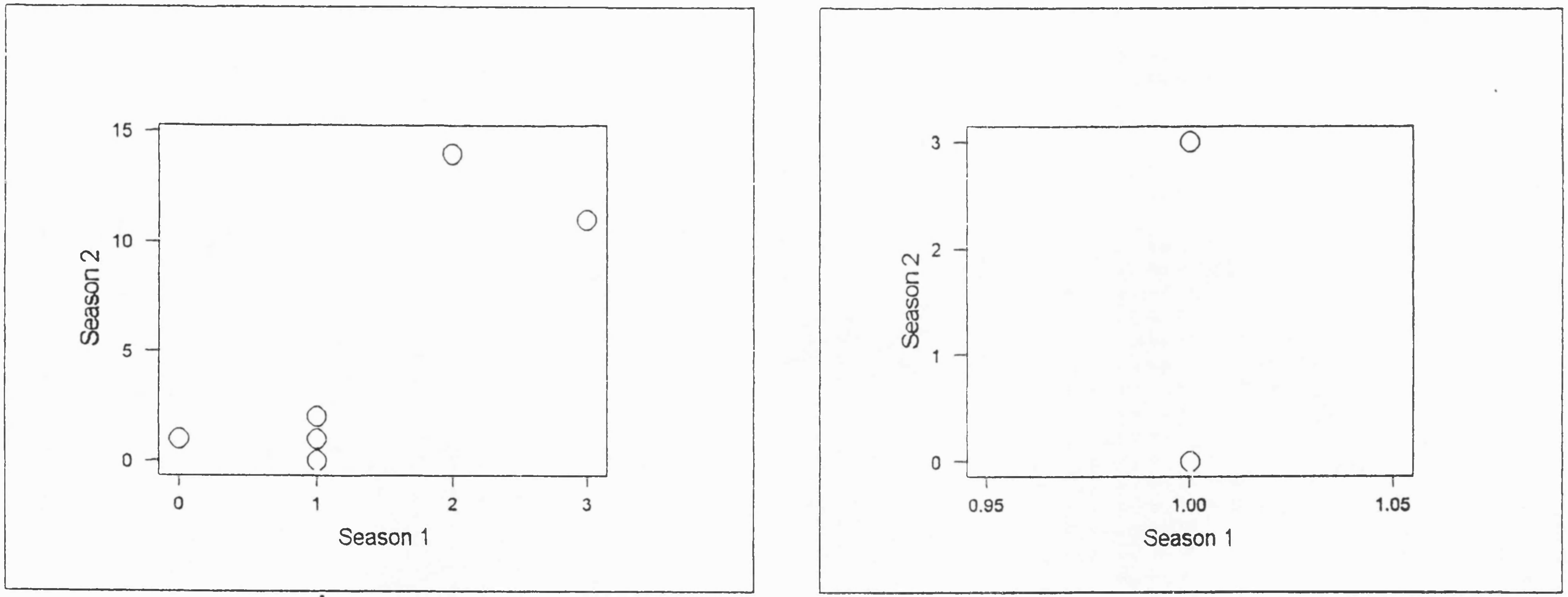
Figure 22 (a) and (b), the main effects plots for year 1 show W5 had the greatest number of leaves, but not the largest ELA. This indicates that the rosette was compact, comprising many small leaves. In contrast, M1 had below the average number of leaves but had the greatest ELA. This indicates that leaves of this clone were longer lived and more elongated than a rosette producing many new leaves. W3 had the least number of leaves and the smallest ELA. This indicates that this clone had a rosette that remained compact and that the individual leaves were long lived. However, an alternative interpretation for W3 is that new leaves were continuously being cropped by field slugs and that plants responded by producing a few new leaves. If the foliage was completely removed then plants persisted for short periods of time as a tap root. Year 2 showed a different picture. The two plots, number of leaves and ELA (Fig 23 (a) and (b)) show that the responses were directly linked. W1 appeared the most vigorous clone, followed by M2, M1 and then W5 before W3. Both years showed weight class differences (Figures 22 and 23 (b)) with plants grown from heavy achenes doing better than plants grown from light achenes. Block differences (Fig 22 and 23 (b)) were reversed in the second year, with plants in block III producing less foliage than plants in block I. This suggests that ash (soil) gradient has an effect. Block I could have been on the more fertile soil, although this was not tested, so all plants had a better start than those on the supposedly poorer soil of block III. By the second year, the grass had become very lush. This may have been the reason for plants producing longer but fewer leaves. Grass in block III was much shorter and finer than in the other blocks, so given the same environmental conditions, plants in this situation produce more leaves but a smaller ELA than plants in the other blocks. There was no correlation between leaf number and ELA with time. It seems that the plants built up numbers of leaves before flowering. Resources were then allocated to flowering and achene production. No new leaves were formed during this reproductive period and so leaf number fell with natural wastage, but leaves that remained increased in area, so overall, ELA increased. Year 2 showed a similar pattern for the number of leaves. The ELA rose at the start of the year and then fell steadily towards the end of the season apart from a small increase at the start of July, after flowering and achene production.

The capitula and achene production (viable achene number and total achene weight) of this sub-set of plants for the two seasons mirrors closely the results of the greenhouse plants reported in the previous chapter. With just one or two exceptions (two plants from W1 and one from W5) a trade-off is seen between the two seasons. If capitula are produced in the first season, fewer and sometimes no capitula are produced in the second season . But if none are produced in the first season, then some are invariably produced in the second. This is reflected in both

Figure 24 **Capitula production in the field over 2 seasons**

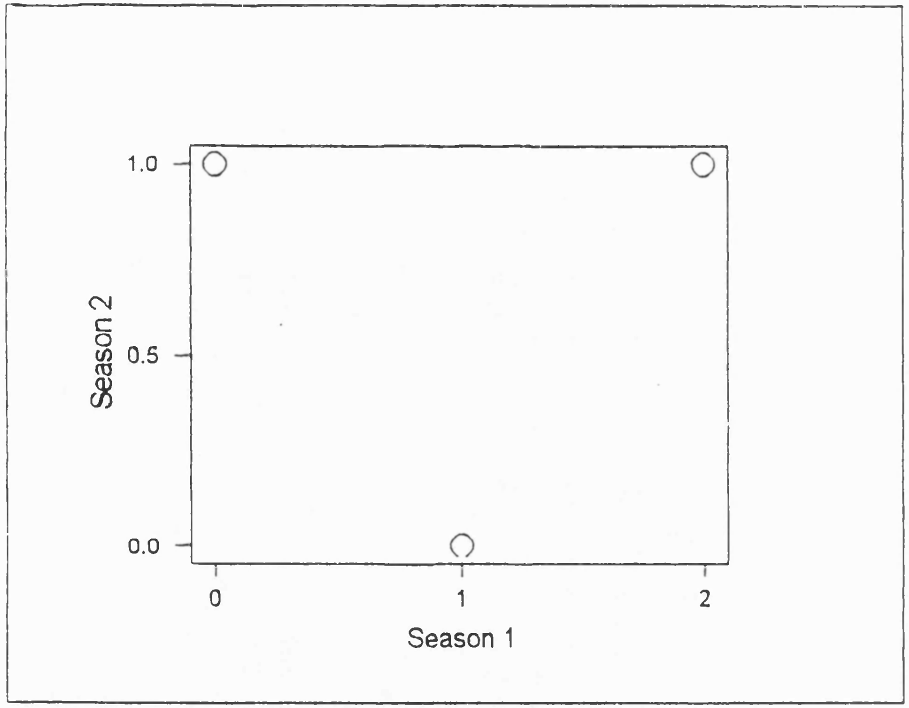
(a) W1 plants

(b) W3 plants

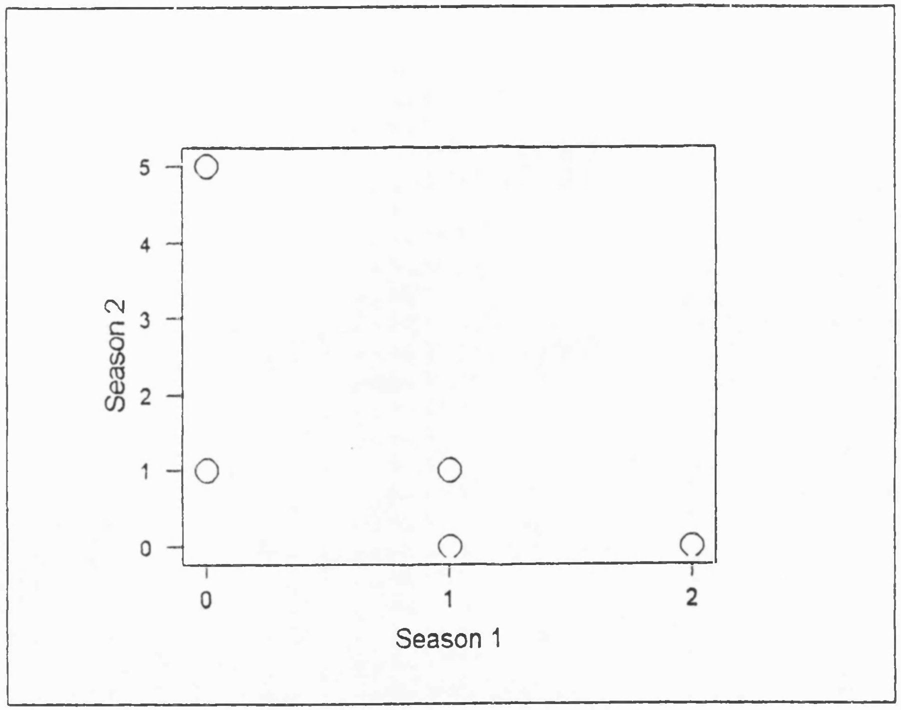


Capitula production in the field over 2 seasons

(c) W5 plants



(d) M1 plants



(e) M2 plants

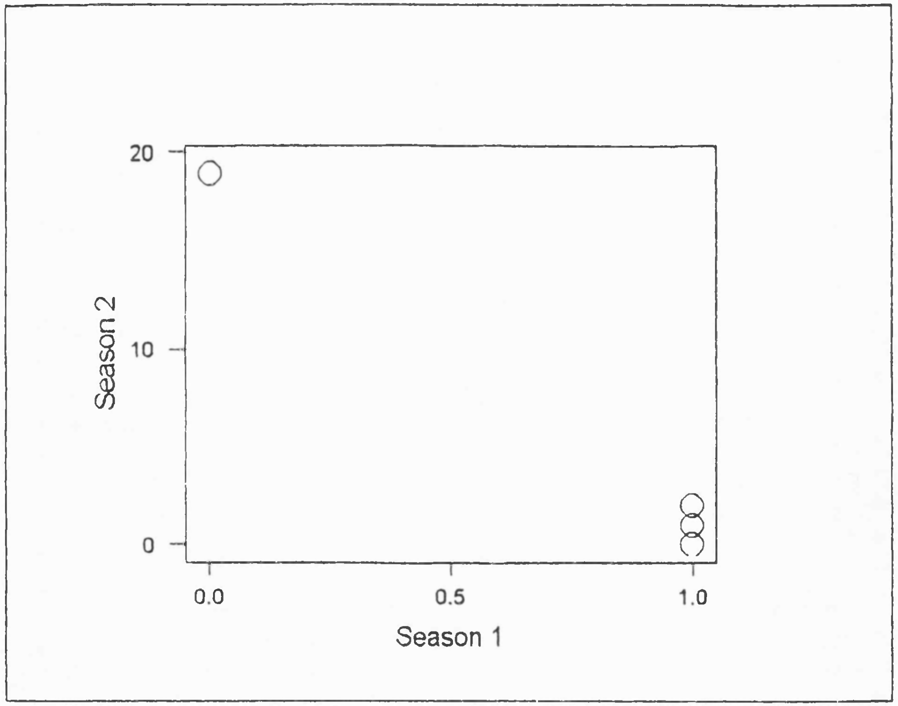
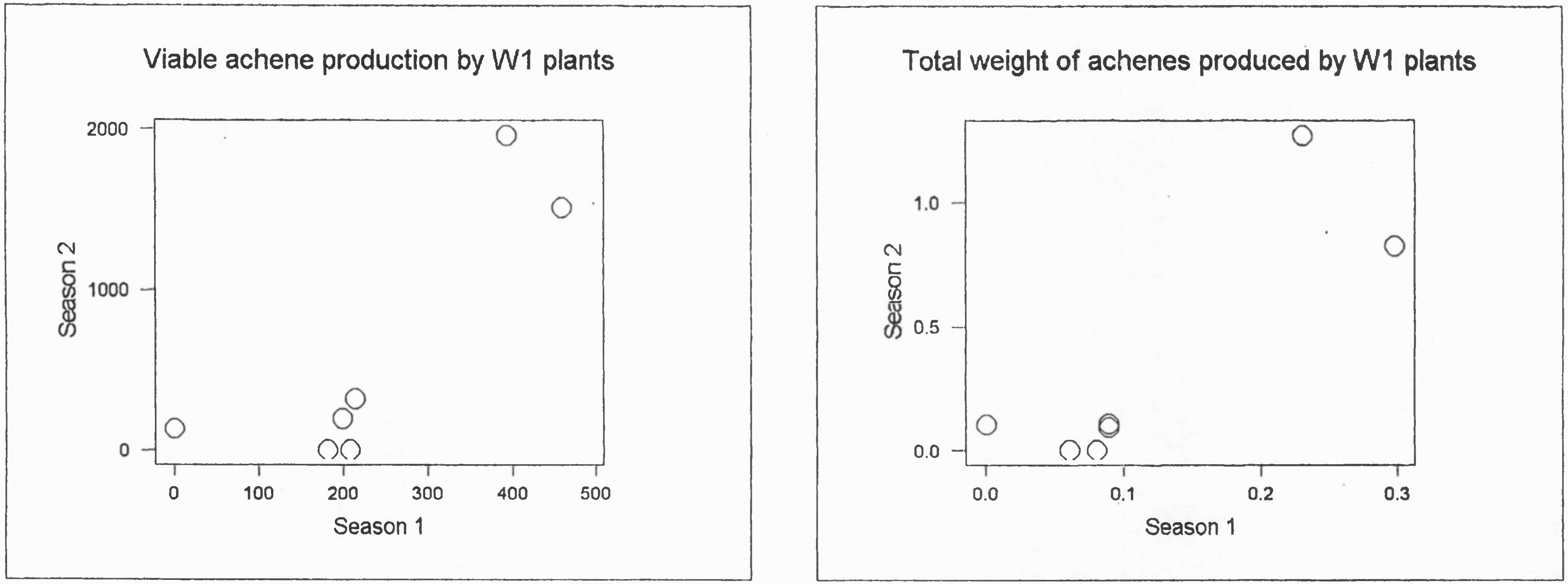


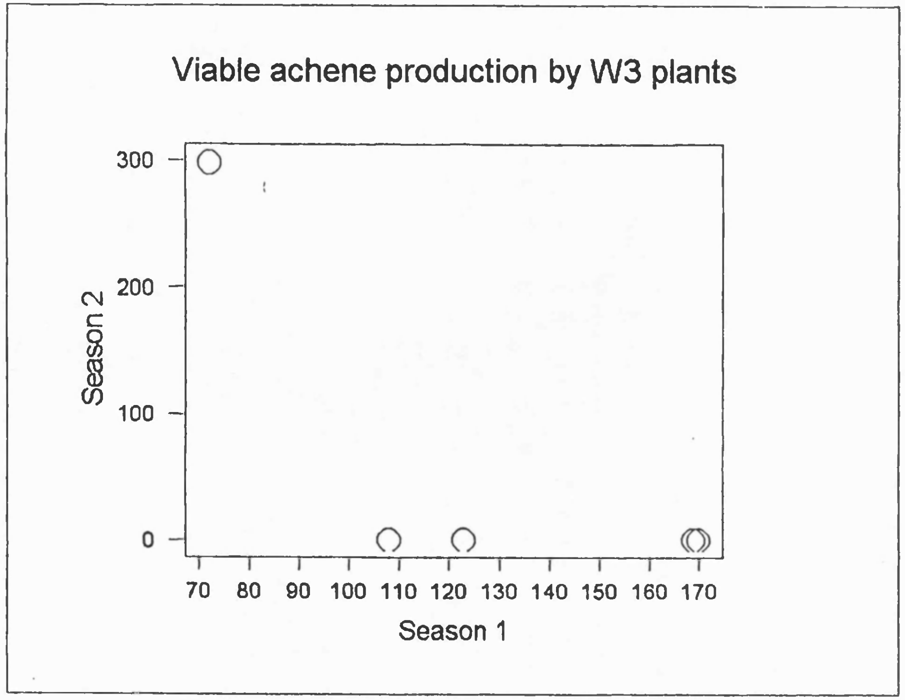
Figure 25 Achene production for W1 plants in field experiment

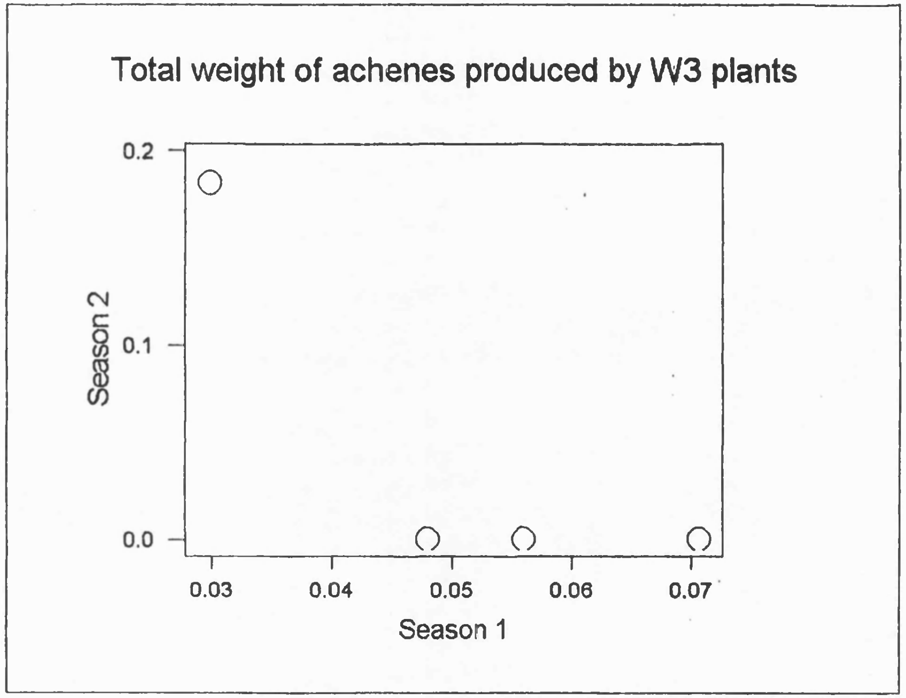
(a)



Achene production for W3 plants in field experiment

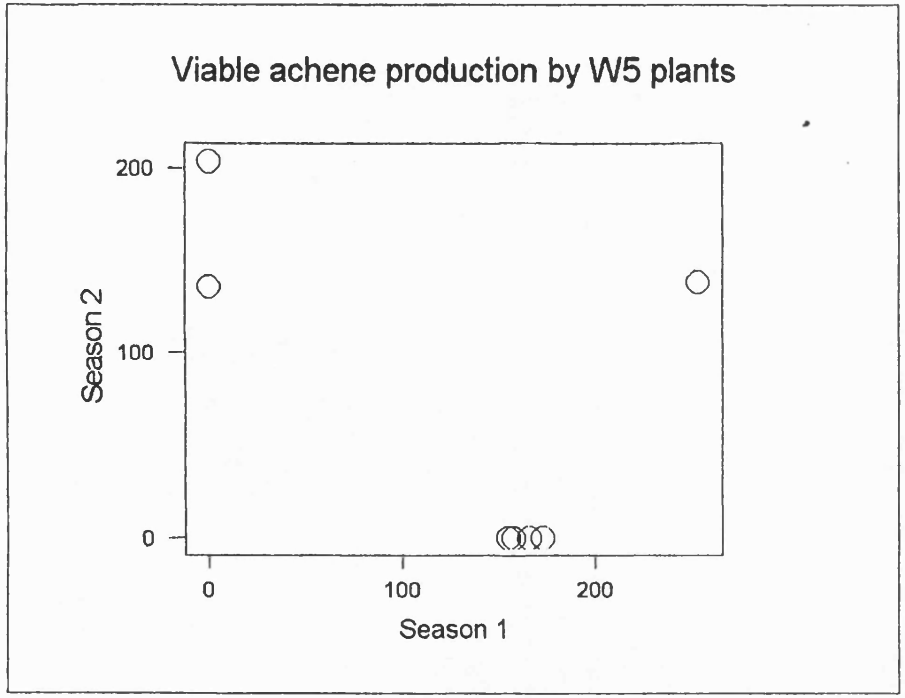
(b)

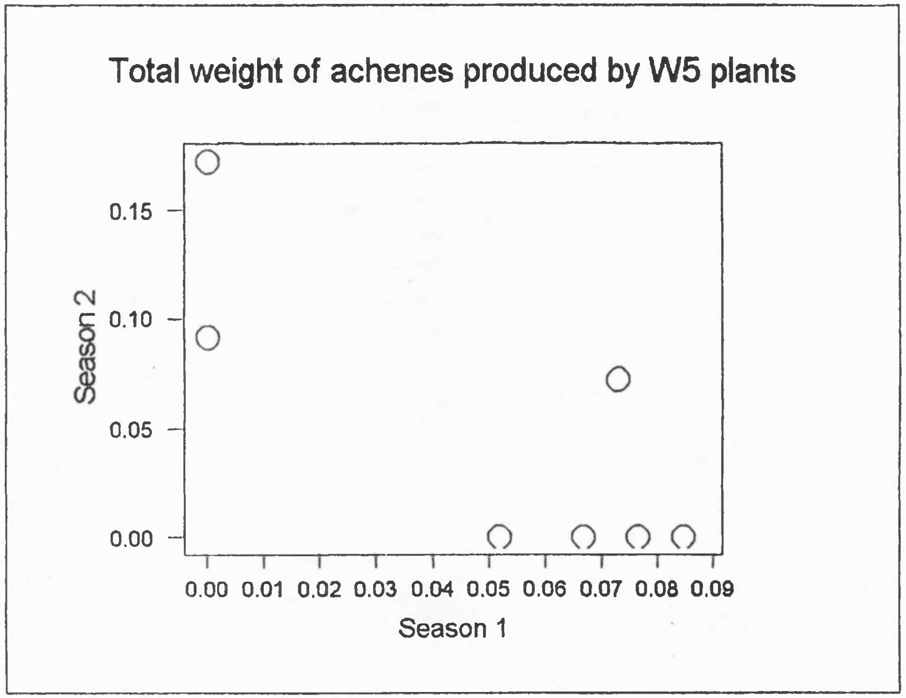




Achene production for W5 plants in field experiment

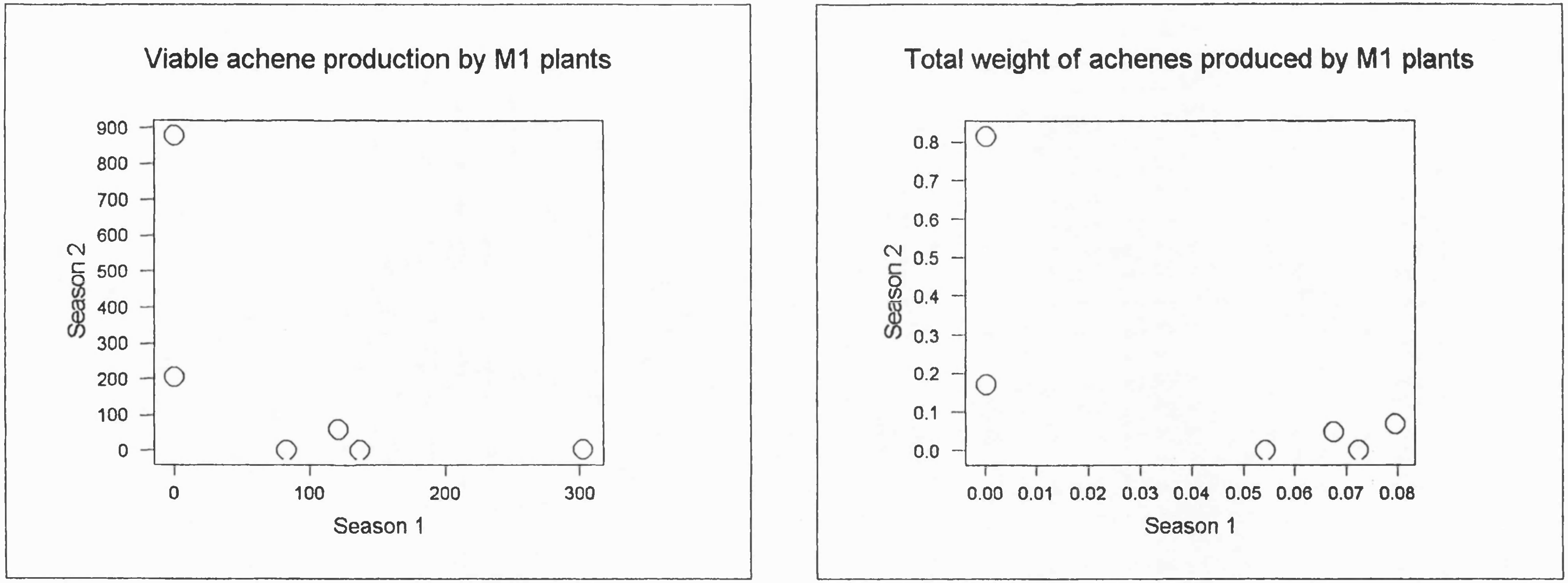
(c)





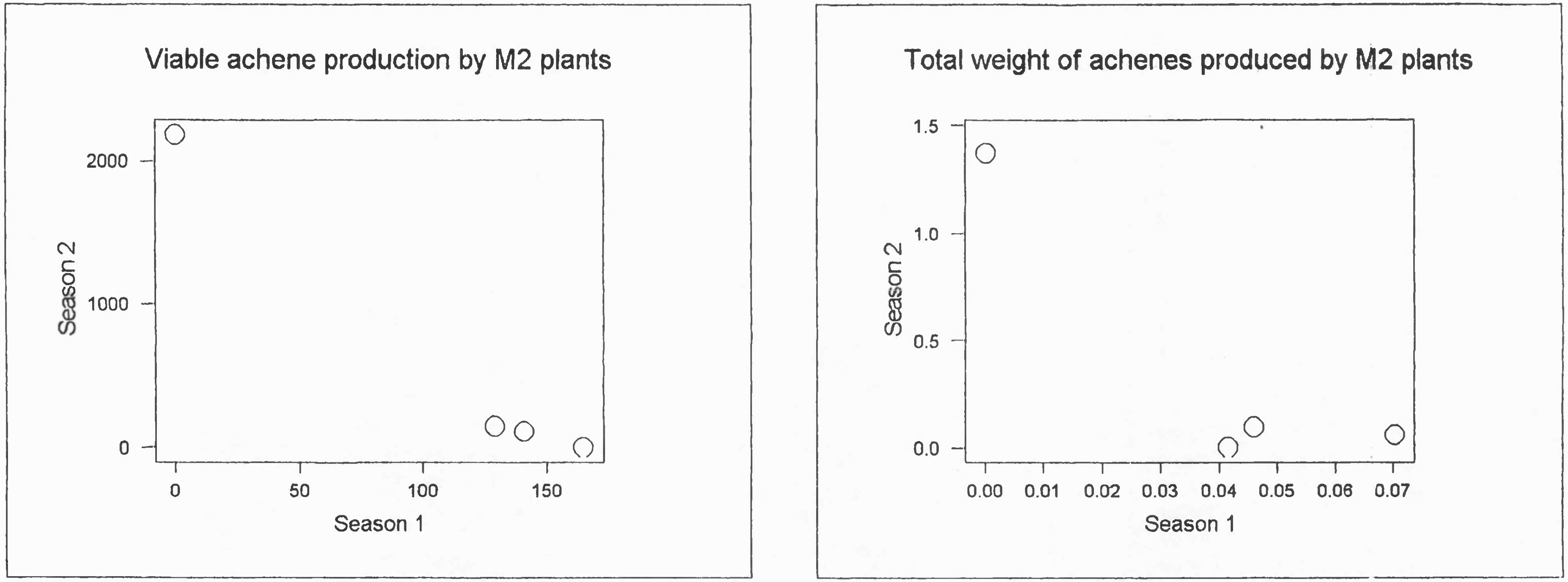
Achene production for M1 plants in field experiment

(d)



Achene production for M2 plants in field experiment

(e)



the number of viable achenes and the total achene weight.

As both field and greenhouse grown plants follow the same trend, it is reasonable to conclude that the results obtained from the greenhouse experiment are not artefacts, but are a reflection of what happens in the field. However it must be noted that capitula and achene production are much lower in the field. This may be because plants in the field experience more stress than plants grown in the greenhouse.

6.2 Environmental Sensitivity

6.2.1 Introduction

Environmental sensitivity provides a measure of the extent to which genotypes respond to changes in the environment. A genotype's environmental sensitivity with respect to a character is the regression of its own value for this character on the environmental value (Falconer 1981). The environmental value for a character in a specified environment is the mean value of this character (estimated from individuals representing several genotypes) in the environment. The regression is performed over several environments. The slope of the regression line measures the environmental sensitivity of a genotype. A significant slope indicates that changes in the phenotype are, in part, determined by changes in the environment. A high correlation coefficient, r_A, for a genotype indicates that changes in the environment explain most of the changes in the phenotype exhibited by that genotype. Two genotypes could have the same slope but different r_A values. This would indicate equal sensitivities but that the environment explained more of the variation in phenotype for the genotype with the higher r_A than for the other genotype. Genotypes with significantly different slopes show significantly different responses to variation in the environment. A regression coefficient of 1.0 represents the average sensitivity of all genotypes (Falconer 1981).

6.2.2 Materials and Methods

The 5 clones that were used in the field experiment were involved in this experiment (ie W1, W3, W5, M1 and M2). Eight replicates of each clone were grown in each of nine environments. Two of these environments were produced in the greenhouse. These were: (1) pot grown, (2) NFT (nutrient film technique). The remaining seven environments were produced in the field station. These included: (3&4) bare soil; planted in grassland (5&6); and grown in pots (7&8). These three environments were repeated at two different times of year, hence the dual numbering. Lastly, plants grown from achenes weighing more than 0.7mg were planted into bare soil (environment 9).

Achenes were germinated and potted on (as described in previous sections) before being allocated to a specific environment. Those to be pot grown were transferred to 6" pots. The greenhouse pot grown plants were randomly arranged on a bench covered with capillary matting. At the same time, plants allocated to the NFT environment were positioned in the NFT channels. Both environments were maintained for three months. Plants allocated to the field station environments were planted in rows 0.5 metres apart in a strip of grassland alongside the main plot and in the adjacent bare soil. Plants were assigned randomly to planting positions in these rows. Depending on the treatment, plants were either directly planted into the soil or they were retained in their pots which were buried in the soil up to their rims. These rows were protected by an electric fence. The first batch of plants allocated to the field environments were planted in May 1993 and harvested three months later. The second batch was planted in November 1993 and were to be harvested in February 1994. However, this part of the experiment was vandalised over the Christmas period and had to be repeated later in March 1994. Harvesting involved digging up the plants, measuring the root crown diameter to establish a mean value and removing the foliage at the root crown and ascertaining its dry weight. (All procedures adopted are as described in section 6.1.5). A mean value of all genotypes for each environment (the environmental value) was calculated. The genotypic value, which is the mean for each genotype in each environment, was also calculated. Regressions were performed of genotypic value against environmental value.

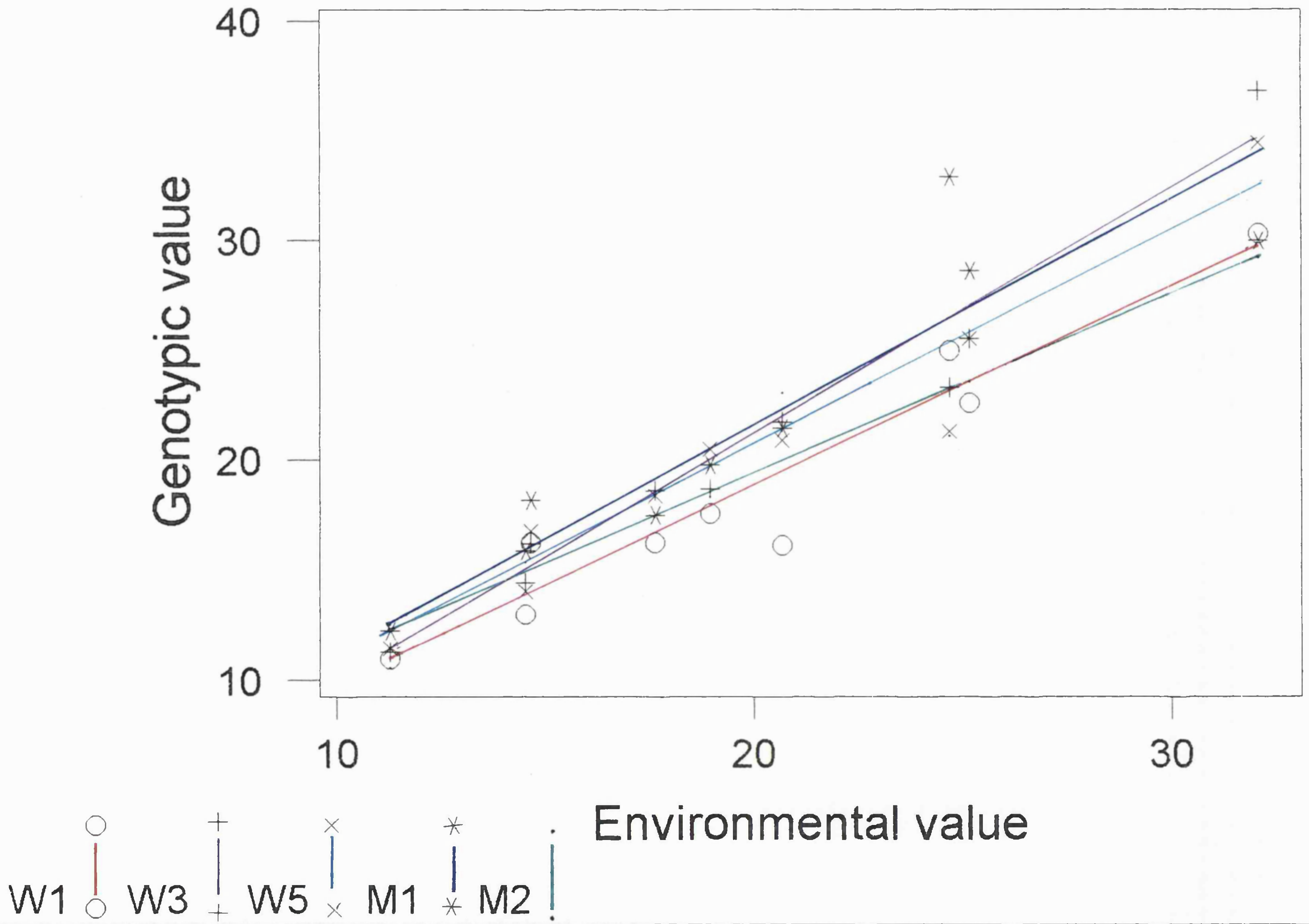
6.2.3 Results

The regressions for root crown diameter are summarised in Table 38. The regression equations follow the general form y = mx + c, where m is the slope and c is the intercept. The slope of the regression line measures the environmental sensitivity of the clone. The regressions for dry weight of foliage are summarised in Table 39. Also see Figure 26 (a) and (b).

Table 38 Summary of regressions of genotypic values against environmental values for root crown diameter

Clone	Slope (m)	Intercept (c)	r^2
W1	0.914	0.430	92.7%
W3	1.130	-1.830	95.9%
W5	1.000	0.290	93.4%
M1	0.993	-1.990	83.0%
M2	0.816	-3.100	92.5%

(a) Environmental sensitivity using root crown diameter data



(b) Environmental sensitivity using dry weight data

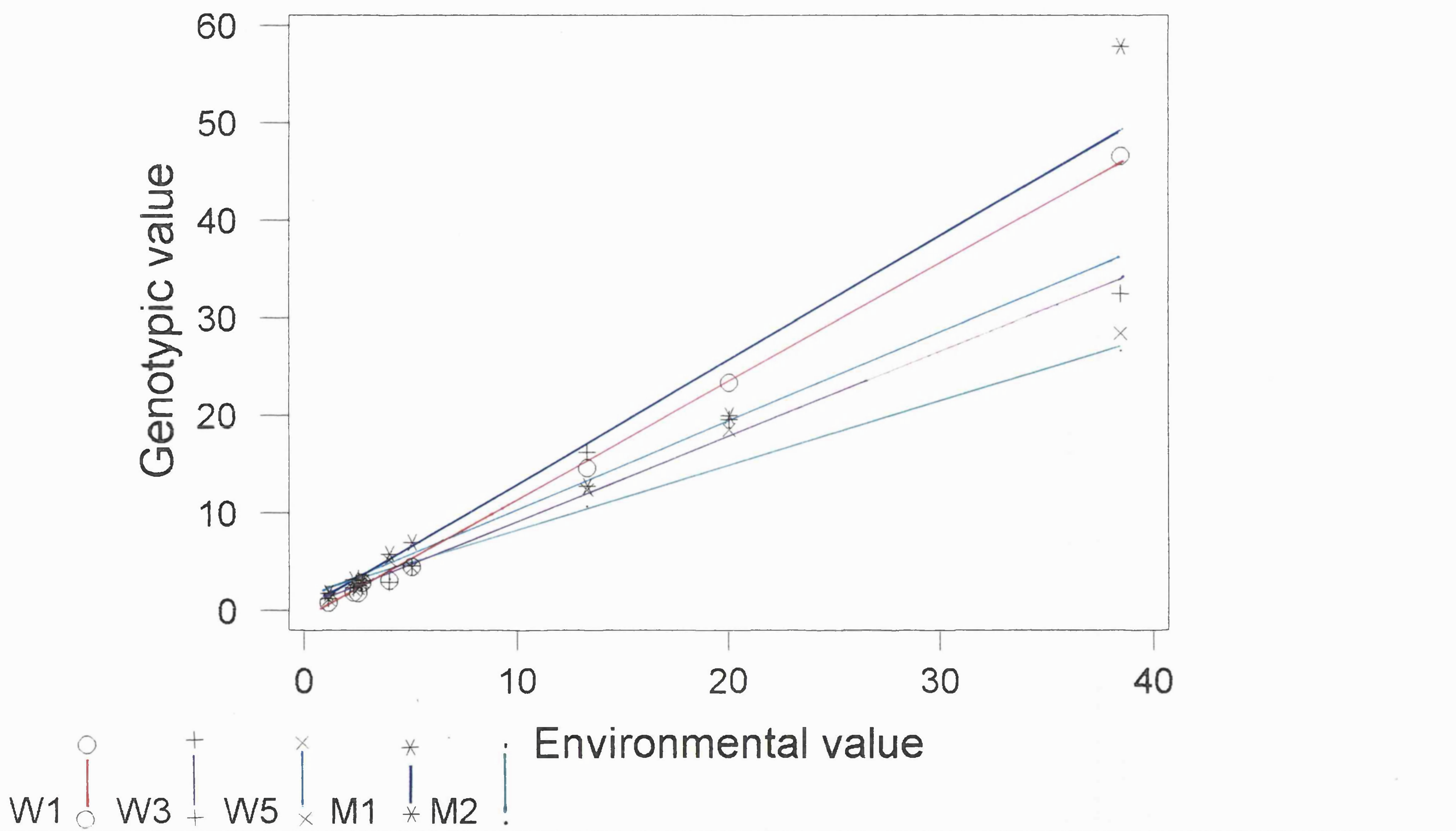


Table 39 Summary of regressions of genotypic values against environmental values for dry weight of foliage

Clone	Slope (m)	Intercept (c)	r^2
W1	1.240	-1.310	99.9%
W3	0.869	0.815	97.6%
W5	0.753	1.080	98.2%
M1	1.420	-1.520	96.0%
M2	0.716	0.934	97.3%

6.2.4 Discussion

For root crown diameter, the order of clones from high to low sensitivity is: W3 W5 M1 W1 M2. For dry weight of foliage the order is : M1 W1 W3 W5 M2. Although M2 shows the least sensitivity for both characters, overall, it seems from this limited sample that relative environmental sensitivity in *Taraxacum* may be a character-specific rather than a clone-specific characteristic. For root crown diameter, the slopes of the regression lines for M2 and W3 are significantly different from each other at $p < 0.05$ although neither W3 nor M2 is significantly different from the rest. For dry weight, the slopes of the regression lines for M2 and W5 are not significantly different, M2 and W3 are significantly different $p < 0.1$, but M2 is significantly different from the rest $p < 0.001$. M1 and W1 are significantly different $p < 0.05$ and M1 and the remainder are significantly different at $p < 0.001$.

It is important to appreciate how selection acts on differences in environmental sensitivity. Upward selection (i.e. increase in character: size, root crown diameter et), in a good environment and downward selection in a bad environment favour genotypes with high sensitivity. (In this case, 'good' and 'bad' refer to environments that increase and decrease the character respectively. In the experiment conducted here, a good environment would be one that supplies a high nutrient level). In contrast, upward selection in a bad environment tends to favour genotypes with low sensitivity. That is high sensitivity is selected when selection and the environment act on a character in the same direction, and low sensitivity is selected when selection and the environment act on the character in opposite directions. Consequently, it can be predicted that clone M2 is at an advantage (compared with the other clones) when the environment and selection act in opposite directions; that is, it is at an advantage in poor environments. The environmental sensitivities of the remaining four clones indicate that these could do well across a wide range of environments. It is important to note that, for each character, the coefficient of determination (r^2) is close to 100%. This indicates that changes observed over environments are fully explained by the changes in the environment. A lower value for this coefficient would indicate that non-genetic factors, for example, the current state or developmental stage of the plant significantly influenced its response to environmental changes. Thus the high values of the coefficients can be interpreted as implying that knowledge of the genotype is sufficient to predict the phenotype that will be produced in a particular environment by a particular genotype.

It has been argued that selection among asexual forms has favoured general-purpose genotypes that can persist under a wide range of conditions (Lynch, in Mogie 1992). This general-purpose genotype hypothesis predicts that environmental fluctuations over time will eliminate asexual lineages that possess narrow ecological tolerances, and that asexual populations should therefore evolve to become broadly tolerant of environmental variations. Kenny (1996) used sexual and asexual species of *Erigeron* (*E. philadelphicus* and *E. annuus*) to compare responses to different environments as a test of the general-purpose genotype hypothesis. Their findings suggest that there are no significant differences between the species, and therefore that asexual individuals are no more general-purpose than sexuals.

In this research asexuals only have been compared in 9 environments. The results suggest that at least four of the clones may be able to tolerate a wide range of environments and may possess general-purpose genotypes. However, investigations involving more characters would be needed before any firm conclusions could be made on this issue.

Chapter 7

7.1 Summary

The results of this research can be summarised as follows:

- Achene weight range per capitulum is non-normally distributed. The number of achenes, and also the weight range, vary between capitula, for all clones.
- Germination of achenes can be erratic. Lighter achenes are generally less viable than heavier achenes. Achene weight is the best predictor of germination. Time in storage can affect viability. During storage, lighter achenes lose viability at a faster rate than heavier achenes.
- Heavier achenes contain heavier and longer embryos.
- Plants germinating from mid-range achene weights have slower growth rates in early stages than those from both lighter and heavier achenes. Different clones exhibit different growth rates. Achene weight influences growth rate over periods up to 77 days.
- All achenes show a similar pattern of growth after germination. Allocation is preferentially directed towards shoots during the early stages of growth. Growth of roots increases when leaves are producing enough metabolites to become 'sources' instead of 'sinks'.
- Under controlled conditions the size and duration of leaf cohorts are independent of initial achene weight and also of clone identity.
- Under controlled conditions, the time to flowering shows clonal differences. There is a negative correlation between reproduction early in life and subsequent reproduction. Achene production for most plants is not correlated with initial achene weight.
- In a natural environment, there is a consistent pattern to reproduction, with most plants producing more capitula in the first year than in the second. This is independent of clone identity, although flowering behaviour within a clone remained constant for both years.

- Under field conditions, plants grown from heavier achenes produced more capitula than those grown from lighter achenes in each year.
- Environmental sensitivity experiments indicate that four of the five clones in the experiment are able to tolerate a wide range of environments.

7.2 General discussion

This research has not attempted to investigate all aspects of fitness in *Taraxacum*. Fitness has two components: survivorship and fecundity. The investigations reported in this thesis are almost solely concerned with aspects of reproduction. A small experiment regarding survivorship of achenes in the field was conducted, but more investigations would be needed to answer questions about survivorship, and therefore, fitness.

The number and weight range of each capitulum of the initial experimental material were different. The position of these capitula in the flowering sequence of the parent plants is unknown.

It has been suggested that big plants produce big seeds (Harper *et. al.* 1970) and Bostock and Benton (1979) have attempted to quantify differences in numbers of achenes per capitulum between wild and experimental plants. They show that *Taraxacum* has a higher reproductive capacity when pot grown than when field grown and they conclude that: "there is no simple relationship between number of achenes produced and their weight". This statement was verified by my experiments with both pot-grown and field-grown plants. In experiments with semi-arid species, Leishman and Westoby (1994) using 18 different species (such as *Acacia excelsa, Atriplex holocarpa, Calotis cunefolia, Enneapogon cylindricus, Eucalyptus opaca* and *Hakea leucoptera* to name a few), found differences between field and greenhouse grown plants, with larger seeds providing an advantage for seedling establishment in low soil moisture conditions. Wulff (1986) found no correlation between mean seed weight per plant and total numbers of seeds produced per plant in the legume, *Desmodium paniculatum*, but found a negative correlation between seed size (weight) and seed number at the level of single fruits.

The position of seeds can be important; seeds in the most favourable positions procure more resources and in consequence are large, and this variation of seed size with position is observed in *Rumex crispus* and *Rumex obtusifolius* (Cavers and Harper 1966), *Lomatium grayi* (*Umbelliferae*) (Thompson 1984) and *Tragopogon dubious* (McGinley 1989). I did not attempt to quantify any relationship that might exist between individual achene weight and its position on the capitulum.

The most important consequence of achene size is in the ability to germinate. Chapter three reports on the germinations experiments over a period of a year. I find that germination rate increases with achene weight up to weights of 0.5-0.6 mg. Above this weight range, germination rate is 95% - 100%. Other studies have found both similar and conflicting results, indicating that the relationship observed in *Taraxacum* between seed weight and germination is not universal. In *Sesbania bispinosa* (Sharma *et.al.* 1978) germination rate increases with seed weight. For *Medicago sativa* (Cooper *et.al.* 1979) germination decreases with increasing seed weight and for *Rumex* spp. seed weight has no effect at all on germination rate (Cideciyan and Malloch 1982).

Seed weight may be the least plastic of plant attributes and according to Kane and Cavers (1992). Thus, it would appear beneficial for plants, to maintain seed size, even though the cost of this may be a reduction in the number of seeds per plant (Smith and Fretwell 1974). *Taraxacum* plants might benefit from producing fewer but larger achenes, rather than a large number of small achenes, if germination of larger achenes was greater than those of smaller achenes. Moreover, small seeds could produce small embryos which develop into seedlings with slow growth rates (Moore and Cavers 1985). The research presented in this thesis shows that lighter achenes do contain shorter, lighter embryos. It is possibly the size of the embryo that controls germination, in *Taraxacum* where endosperm is reduced to a few crushed cells within the achene. A larger embryo contains more cells that, on imbibition, can expand and ultimately differentiate into recognisable plant organs. It has been suggested that variable seed size may confer advantages to a plant dispersing seeds into a heteregeneous environment (Kane and Cavers 1992).

Small seeds not only have a lower germination rate (generally) but also produce seedlings which are small and have a lower survivorship than seeds which are large (Schaal 1980). This view is supported by Fenner (1985). The non-destructive harvesting experiment (chapter 4) does show differences in early growth rate, with mid-weight range achenes having a slower growth rate than seedlings from other weight classes. Seedlings germinated from heavier achenes had a greater growth rate overall, and at 77 days were the largest. Seed size accounts for a significant proportion of seedling size in pearl millet, but there are differences among genotypes or populations that are not associated with seed size (Maiti *et. al.* 1990). In wild radish (*Raphanus raphanistrum*), seed size has a strong effect on emergence and early growth of seedlings, but no consistent effect upon final plant size (Stanton 1984). Using the same species Choe *et.al.* (1988) found that seed size did not affect allocation to above or below ground organs. My root/shoot allocation experiment (chapter 4) supports this view.

The premise of all adaptive interpretations of seed size (Westoby *et.al.* 1992) is that seedlings from larger seeds have greater metabolic reserves in embryo and endosperm available to them. In *Taraxacum,* these reserves would be located in the embryo, the size of which would be positively correlated with the amount of reserves. Following germination, seedling size will increasingly be determined by relative growth rate rather than by the initial size of the embryo. Seedlings from heavier seeds have often been found to have a similar or lower RGR than seedlings from lighter seeds (Zhang 1994). The correlation between seed weight and seedling weight may be strong shortly after germination, but it can be expected to decrease as seedlings become older. This view is supported by Gross (1984).

As the seedlings develop into adult plants, any benefits from having germinated from a larger seed is diminished. In both the leaf-turnover (chapter 4) and flowering sequence (chapter 5) experiments, that were conducted under controlled conditions, no correlation was found between initial achene weight and subsequent performance. Thus the size, and duration of leaf cohorts were independent of both initial achene weight and clone. Also, the time to flowering showed differences between clones but showed no differences that were due to initial achene weight differences (Bostock and Benton 1979). Achene production showed no correlation with initial achene weight for most plants. However, there is a cost-benefit relationship between time of flowering and subsequent reproduction. The results of chapter 5 agree with those of Law (1979) who states that reproduction early in life affects subsequent reproductive ability. In the natural environment, most plants produce more flowers in the first year of the experiment than in the second. This could have been due to greater predation in the second year or as a reflection of Law's hypothesis. In work with a short lived perennial, *Cassia marilandica*, Piper (1992) found that reproductive effort peaked in the second year, and declined after that, although he states that the four year duration of the experiment may be insufficient time to characterise long-term yield patterns in this species. The same could be said of the two year duration of the field experiment reported in this thesis.

The conclusions drawn from this work are that all plants studied produce capitula with a unique weight range and number of achenes. Achene weight, and in consequence embryo weight, is the critical determining factor in germination success. Any advantage in having germinated from a heavier achene persists during early seedling establishment, but diminishes with plant age. Achene weight affects flowering in field conditions, but has no influence on greenhouse grown plants. However, large scale assessment of field grown plants to investigate any effect achene weight may have on their flowering was not possible within the scope of this research.

The following are recently published references that have not been included in the main text. *Taraxacum officinale* grown in a hydroponic (NFT) system produced more growth than plants grown under an organic system (Letchamo and Gosselin 1995), which supports my results from the environmental sensitivity experiments. The authors note that when plants were defoliated root growth promotion resulted. This may explain why *Taraxacum* is able to regenerate after severe above ground damage. Several papers have been published concerning grazing of *Taraxacum* by molluscs, and in particular by *Derocerus reticulatum* (the field slug) (Henley *et.al.* 1995 a, b, c). These show that *Taraxacum* is heavily grazed by molluscs and that this grazing influences both seedling survival and the fecundity of mature plants. Damage by molluscs can be crucial in determining survivorship of a cohort of seedlings, particularly as changes in seedling palatability occur with age. If a seedling escapes predation, it has a high chance of survival to maturity. The intensity of grazing is greatest in autumn, although spring damage can also reduce seedling survivorship. This does concur with my observations of field damage.

Research into the responses of genotypes of *Taraxacum* to temporal environmental heterogeneity (Vavrek *et.al.* 1996) conclude that, despite seasonal differences, genotypic performances summed across seasons were equivalent, and that persistence of genotypes of contrasting performance through time is expected if long-term fitness values remain similar. No mention is made in the abstract of environmental sensitivity or of a general- purpose genotype.

Finally, two papers report research that uses *Taraxacum officinale* as an indicator species for contamination by trace metals (Kabata-Pendias and Dudka 1991 and Cook *et.al.* 1994). It is perhaps surprising that this species has not been used before for this purpose, especially as it occurs widely in urban and road-side areas where contamination by heavy metals in traffic fumes can be widespread.

The research reported here could be extended by a greater investigation into environmental sensitivity. If more characters in a greater number of environments were involved it might be possible to ascertain if any clones possess general-purpose genotypes. As mentioned earlier in this chapter, only aspects of fecundity have been explored. It would add to the existing data if an investigation into survivorship could be conducted and this knowledge added to provide an insight into fitness of *Taraxacum* clones.

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Appendix I a

Achene weight (in mg) for Initial Material, Location W.

	W1	W2	W3	W4	W5
1	0.2290	0.1633	0.1140	0.1662	0.1232
2	0.2551	0.1733	0.1442	0.1806	0.1543
3	0.2705	0.3100	0.2169	0.1941	0.1661
4	0.2739	0.3180	0.2593	0.2116	0.2386
5	0.2827	0.3575	0.2817	0.2776	0.2456
6	0.2847	0.3667	0.2909	0.3035	0.2482
7	0.2927	0.3772	0.3254	0.3038	0.2539
8	0.2997	0.3807	0.3437	0.3057	0.2740
9	0.3353	0.3911	0.3557	0.3364	0.2993
10	0.3395	0.3922	0.3612	0.3446	0.3215
11	0.3791	0.4026	0.3650	0.3524	0.3656
12	0.4204	0.4046	0.3693	0.3617	0.3700
13	0.4467	0.4069	0.3696	0.3716	0.3808
14	0.4621	0.4095	0.3745	0.3784	0.3825
15	0.4626	0.4099	0.3881	0.3840	0.3875
16	0.4641	0.4115	0.3895	0.4423	0.4233
17	0.4660	0.4117	0.4097	0.4427	0.4449
18	0.4706	0.4162	0.4187	0.4459	0.4473
19	0.4770	0.4184	0.4610	0.4500	0.4637
20	0.4900	0.4208	0.4623	0.4616	0.4709
21	0.5014	0.4226	0.4683	0.4629	0.4713
22	0.5045	0.4226	0.5023	0.4673	0.4822
23	0.5191	0.4237	0.5251	0.4739	0.4835
24	0.5202	0.4260	0.5265	0.4862	0.4864
25	0.5241	0.4280	0.5277	0.4937	0.4866
26	0.5303	0.4291	0.5346	0.5012	0.5009
27	0.5325	0.4304	0.5373	0.5155	0.5059
28	0.5400	0.4321	0.5408	0.5167	0.5166
29	0.5402	0.4325	0.5411	0.5178	0.5173
30	0.5437	0.4346	0.5443	0.5186	0.5210
31	0.5445	0.4368	0.5553	0.5228	0.5213
32	0.5682	0.4385	0.5719	0.5253	0.5218
33	0.5700	0.4393	0.5861	0.5267	0.5290
34	0,5744	0.4414	0.5870	0.5292	0.5292
35	0.5950	0.4441	0.5991	0.5332	0.5303
36	0.6014	0.4473	0.5994	0.5382	0.5393
37	0.6043	0.4474	0.6000	0.5387	0.5474
38	0.6062	0.4501	0.6131	0.5432	0.5494
39	0.6117	0.4509	0.6145	0.5458	0.5495
40	0.6138	0.4514	0.6204	0.5463	0.5535
41	0.6189	0.4610	0.6228	0.5478	0.5619
42	0.6217	0.4692	0.6240	0.5504	0.5622
43	0.6298	0.4770	0.6244	0.5506	0.5633
44	0.6350	0.4803	0.6283	0.5551	0.5638
45	0.6387	0.4844	0.6337	0.5622	0.5661
46	0.6524	0.4872	0.6341	0.5622	0.5688
47	0.6551	0.4928	0.6377	0.5635	0.5787
48	0.6576	0.4935	0.6415	0.5703	0.5799
49	0.6587	0.4981	0.6490	0.5717	0.5813
50	0.6810	0.4994	0.6492	0.5756	0.5849
51	0.6633	0.4998	0.6555	0.5775	0.5853
52	0.6636	0.5001	0.6635	0.5780	0.5859
53	0.6642	0.5046	0.6667	0.5789	0.5932
54	0.6736	0.5054	0.6689	0.5875	0.5943
55	0.6906	0.5317	0.6738	0.5947	0.5959
56	0.6907	0.5680	0.6745	0.5949	0.6018
57	0.6919	0.5808	0.6779	0.6021	0.6039
58	0.6973	0.5858	0.6828	0.6048	0.6112
59	0.6976	0.5871	0.6886	0.6063	0.6219
60	0.6983	0.6334	0.6891	0.6157	0.6230
61	0.7080	0.6336	0.6914	0.6199	0.6310

	W1	W2	W3	W4	W5
62	0.7089	0.6406	0.6916	0.6338	0.6311
63	0.7095	0.6477	0.6926	0.6364	0.6314
64	0.7205	0.6484	0.6926	0.6390	0.6338
65	0.7206	0.6487	0.6946	0.6404	0.6345
66	0.7268	0.6565	0.6996	0.6486	0.6358
67	0.7297	0.6841	0.7002	0.6554	0.6450
68	0.7300	0.6892	0.7007	0.6570	0.6472
69	0.7310	0.6907	0.7044	0.6610	0.6479
70	0.7447	0.6949	0.7067	0.6627	0.6489
71	0.7465	0.7002	0.7096	0.6632	0.6517
72	0.7489	0.7029	0.7097	0.6690	0.6518
73	0.7506	0.7031	0.7140	0.6711	0.6525
74	0.7511	0.7180	0.7142	0.6736	0.6528
75	0.7557	0.7315	0.7147	0.6795	0.6555
76	0.7578	0.7323	0.7161	0.6797	0.6578
77	0.7597	0.7524	0.7161	0.6805	0.6590
78	0.7660	0.7591	0.7173	0.6867	0.6650
79	0.7675	0.7654	0.7228	0.6882	0.6671
80	0.7712	0.7680	0.7248	0.6915	0.6674
81	0.7726	0.7690	0.7259	0.6927	0.6766
82	0.7738	0.7711	0.7265	0.6974	0.6779
83	0.7741	0.7722	0.7270	0.6977	0.6781
84	0.7749	0.7745	0.7389	0.7011	0.6787
85	0.7753	0.7843	0.7448	0.7050	0.6832
86	0.7775	0.7854	0.7464	0.7124	0.6886
87	0.7783	0.7900	0.7480	0.7153	0.6901
88	0.7786	0.7968	0.7487	0.7176	0.6911
89	0.7808	0.7976	0.7488	0.7204	0.6920
90	0.7848	0.8091	0.7496	0.7240	0.6940
91	0.7850	0.8124	0.7502	0.7253	0.6955
92	0.7851	0.8216	0.7555	0.7274	0.6982
93	0.7913	0.8250	0.7557	0.7292	0.6988
94	0.7924	0.8255	0.7575	0.7302	0.7008
95	0.7951	0.8346	0.7580	0.7313	0.7014
96	0.7972	0.8385	0.7606	0.7322	0.7020
97	0.7992	0.8413	0.7607	0.7331	0.7021
98	0.8013	0.8450	0.7609	0.7334	0.7048
99	0.8114	0.8497	0.7661	0.7346	0.7048
100	0.8123	0.8546	0.7662	0.7349	0.7066
101	0.8146	0.8578	0.7681	0.7353	0.7093
102	0.8167	0.8639	0.7698	0.7362	0.7108
103	0.8169	0.8682	0.7701	0.7367	0.7128
104	0.8207	0.8802	0.7707	0.7387	0.7142
105	0.8238	0.8850	0.7724	0.7428	0.7150
106	0.8266	0.8861	0.7730	0.7466	0.7204
107	0.8277	0.8939	0.7748	0.7470	0.7211
108	0.8311	0.9365	0.7751	0.7490	0.7218
109	0.8352	0.9449	0.7754	0.7491	0.7233
110	0.8392	0.9460	0.7809	0.7548	0.7240
111	0.8403	0.9521	0.7841	0.7572	0.7250
112	0.8472	0.9541	0.7857	0.7613	0.7265
113	0.8530	0.9662	0.7871	0.7618	0.7274
114	0.8569	0.9725	0.7873	0.7629	0.7298
115	0.8573	0.9725	0.7879	0.7654	0.7336
116	0.8589	0.9794	0.7884	0.7690	0.7348
117	0.8648	0.9807	0.7886	0.7707	0.7348
118	0.8652	0.9895	0.7904	0.7721	0.7365
119	0.8688	0.9917	0.7927	0.7737	0.7395
120	0.8700	0.9954	0.7928	0.7774	0.7399
121	0.8707	0.9970	0.7935	0.7777	0.7409
122	0.8719	0.9981	0.7966	0.7792	0.7418

	W1	W2	W3	W4	W5
123	0.8788	1.0023	0.7967	0.7807	0.7451
124	0.8822	1.0117	0.7972	0.7817	0.7452
125	0.8843	1.0151	0.8004	0.7834	0.7466
126	0.8887	1.0221	0.8033	0.7839	0.7523
127	0.8919	1.0312	0.8039	0.7861	0.7559
128	0.8920	1.0420	0.8051	0.7867	0.7615
129	0.8960	1.0446	0.8066	0.7879	0.7631
130	0.9046	1.0487	0.8088	0.7891	0.7690
131	0.9084	1.0550	0.8128	0.7946	0.7691
132	0.9099	1.0565	0.8133	0.7973	0.7699
133	0.9154	1.0595	0.8137	0.8007	0.7779
134	0.9162	1.0640	0.8151	0.8025	0.7791
135	0.9193	1.0677	0.8157	0.8056	0.7802
136	0.9255	1.0695	0.8176	0.8076	0.7815
137	0.9265	1.0718	0.8181	0.8105	0.7863
138	0.9277	1.0787	0.8191	0.8132	0.7882
139	0.9340	1.0900	0.8198	0.8133	0.7977
140	0.9392	1.0936	0.8235	0.8134	0.7982
141	0.9423	1.0938	0.8255	0.8140	0.7993
142	0.9519	1.0963	0.8262	0.8152	0.8024
143	1.0181	1.0966	0.8303	0.8210	0.8046
144		1.0970	0.8344	0.8249	0.8068
145		1.1020	0.8345	0.8282	0.8162
146		1.1044	0.8349	0.8295	0.8259
147		1.1054	0.8363	0.8311	0.8491
148		1.1096	0.8389	0.8326	
149		1.1210	0.8443	0.8331	
150		1.1244	0.8482	0.8376	
151		1.1266	0.8497	0.8379	
152		1.1274	0.8532	0.8383	
153		1.1280	0.8537	0.8397	
154		1.1313	0.8584	0.8417	
155		1.1353	0.8775	0.8438	
156		1.1367	0.8809	0.8463	
157		1.1386	1.1150	0.8466	
158		1.1462		0.8479	
159		1.1464		0.8514	
160		1.1469		0.8678	
161		1.1502		0.8703	
162		1.1557		0.8742	
163		1.1561		0.8771	
164		1.1570		0.8841	
165		1.1603		0.8843	
166		1.1636		0.8866	
167		1.1643		0.8890	
168		1.1659		0.8905	
169		1.1717		0.8973	
170		1.1721		0.8994	
171		1.1740		0.9002	
172		1.1758		0.9062	
173		1.1782		0.9091	
174		1.1783		0.9097	
175		1.1784		0.9121	
176		1.1793		0.9169	
177		1.1840		0.9174	
178		1.1866		0.9194	
179		1.1868		0.9257	
180		1.1901		0.9263	
181		1.1921		0.9412	
182		1.2011		0.9437	
183		1.2017		0.9470	
184		1.2061		0.9491	
185		1.2084		0.9526	
186		1.2107		0.9588	
187		1.2231		0.9593	
188		1.2232		0.9656	
189		1.2237		0.9667	
190		1.2255		0.9753	
191		1.2259		0.9852	
192		1.2298		0.9866	
193		1.2378		0.9874	
194		1.2394		1.0086	
195		1.2424		1.0336	
196		1.2446		1.1182	
197		1.2453			
198		1.2457			
199		1.2470			
200		1.2476			
201		1.2495			
202		1.2496			
203		1.2506			
204		1.2533			
205		1.2535			
206		1.2568			
207		1.2571			
208		1.2574			
209		1.2599			
210		1.2682			
211		1.2684			
212		1.2706			
213		1.2848			
214		1.2939			
215		1.2946			
216		1.3010			
217		1.3021			
218		1.3065			
219		1.3147			
220		1.3198			
221		1.3204			
222		1.3241			
223		1.3250			
224		1.3267			
225		1.3281			
226		1.3314			
227		1.3330			
228		1.3537			
229		1.3736			
230		1.3804			
231		1.3817			
232		1.3875			
233		1.4365			

Achene weight (in mg) for Initial Material, Location M.

	M1	M2	M3	M4	M5
1	0.1186	0.1082	0.0902	0.1133	0.1621
2	0.2688	0.1155	0.1534	0.1636	0.2474
3	0.2758	0.1867	0.1977	0.2081	0.2705
4	0.2945	0.1945	0.2653	0.2433	0.3279
5	0.3079	0.2138	0.2837	0.2515	0.3706
6	0.3127	0.2418	0.3120	0.2658	0.3729
7	0.3218	0.2620	0.3289	0.2708	0.3752
8	0.3315	0.2678	0.3843	0.2924	0.3827
9	0.3384	0.2946	0.3923	0.3039	0.3962
10	0.4059	0.3060	0.4403	0.3122	0.4170
11	0.4737	0.3071	0.4744	0.3152	0.4272
12	0.5234	0.3282	0.5538	0.3348	0.4343
13	0.5307	0.3321	0.6715	0.3619	0.5210
14	0.5372	0.3571	0.6729	0.3761	0.5304
15	0.5384	0.3722	0.7191	0.3843	0.5396
16	0.5400	0.3852	0.7370	0.3974	0.5424
17	0.5421	0.3890	0.7469	0.4093	0.6039
18	0.5786	0.4009	0.7534	0.4116	0.6277
19	0.5965	0.4036	0.7545	0.4391	0.6354
20	0.6056	0.4267	0.7678	0.4466	0.6550
21	0.6194	0.4298	0.7690	0.4537	0.6584
22	0.6207	0.4339	0.7748	0.4664	0.6622
23	0.6243	0.4341	0.7812	0.4664	0.6723
24	0.6271	0.4352	0.7864	0.4728	0.6808
25	0.6382	0.4391	0.7931	0.4760	0.6848
26	0.6518	0.4392	0.7959	0.5038	0.6944
27	0.6591	0.4462	0.8040	0.5098	0.6946
28	0.6597	0.4502	0.8127	0.5121	0.7026
29	0.6807	0.4504	0.8137	0.5179	0.7043
30	0.6966	0.4511	0.8209	0.5202	0.7116
31	0.6986	0.4525	0.8281	0.5268	0.7278
32	0.7031	0.4526	0.8373	0.5293	0.7337
33	0.7076	0.4722	0.8411	0.5329	0.7380
34	0.7082	0.4725	0.8452	0.5426	0.7397
35	0.7128	0.4805	0.8461	0.5437	0.7402
36	0.7134	0.4842	0.8506	0.5500	0.7419
37	0.7159	0.4844	0.8577	0.5510	0.7518
38	0.7184	0.4955	0.8643	0.5580	0.7585
39	0.7187	0.5074	0.8668	0.5591	0.7609
40	0.7188	0.5087	0.8681	0.5658	0.7688
41	0.7247	0.5208	0.8722	0.5769	0.7862
42	0.7361	0.5244	0.8724	0.5772	0.7868
43	0.7363	0.5249	0.8740	0.5797	0.7872
44	0.7364	0.5285	0.8780	0.5864	0.7938
45	0.7381	0.5365	0.8782	0.5867	0.7972
46	0.7381	0.5456	0.8810	0.5951	0.8049
47	0.7433	0.5527	0.8817	0.6051	0.8149
48	0.7446	0.5536	0.8888	0.6110	0.8152
49	0.7457	0.5548	0.8891	0.6116	0.8175
50	0.7498	0.5614	0.8892	0.6130	0.8236
51	0.7534	0.5614	0.8937	0.6140	0.8349
52	0.7537	0.5702	0.8960	0.6149	0.8353
53	0.7538	0.5802	0.8962	0.6164	0.8410
54	0.7561	0.5822	0.8977	0.6228	0.8439
55	0.7575	0.5866	0.9004	0.6228	0.8636
56	0.7597	0.5877	0.9030	0.6241	0.8642
57	0.7598	0.5884	0.9038	0.6279	0.8660
58	0.7646	0.5894	0.9067	0.6321	0.8719
59	0.7652	0.5939	0.9070	0.6344	0.8830
60	0.7682	0.5962	0.9097	0.6344	0.8937
61	0.7728	0.5970	0.9101	0.6390	0.8995

	M1	M2	M3	M4	M5
62	0.7737	0.5982	0.9119	0.6392	0.9000
63	0.7761	0.5991	0.9130	0.6492	0.9041
64	0.7772	0.5998	0.9150	0.6495	0.9082
65	0.7794	0.6011	0.9195	0.6533	0.9121
66	0.7824	0.6018	0.9202	0.6533	0.9145
67	0.7826	0.6057	0.9214	0.6535	0.9150
68	0.7832	0.6084	0.9304	0.6543	0.9155
69	0.7838	0.6114	0.9322	0.6560	0.9170
70	0.7876	0.6139	0.9331	0.6584	0.9172
71	0.7886	0.6144	0.9333	0.6602	0.9216
72	0.7944	0.6151	0.9349	0.6649	0.9336
73	0.7951	0.6166	0.9372	0.6691	0.9376
74	0.7955	0.6186	0.9376	0.6692	0.9406
75	0.7983	0.6187	0.9386	0.6694	0.9415
76	0.7987	0.6189	0.9394	0.6720	0.9417
77	0.8026	0.6200	0.9405	0.6802	0.9421
78	0.8053	0.6220	0.9413	0.6814	0.9429
79	0.8087	0.6231	0.9435	0.6822	0.9446
80	0.8105	0.6239	0.9441	0.6833	0.9448
81	0.8113	0.6239	0.9513	0.6835	0.9454
82	0.8117	0.6240	0.9531	0.6863	0.9478
83	0.8118	0.6249	0.9537	0.6875	0.9496
84	0.8130	0.6273	0.9543	0.6893	0.9510
85	0.8130	0.6282	0.9545	0.6894	0.9517
86	0.8132	0.6301	0.9580	0.6911	0.9517
87	0.8148	0.6307	0.9589	0.6948	0.9537
88	0.8149	0.6320	0.9592	0.6962	0.9553
89	0.8160	0.6350	0.9628	0.6976	0.9561
90	0.8170	0.6350	0.9645	0.6983	0.9663
91	0.8177	0.6354	0.9673	0.7024	0.9569
92	0.8180	0.6355	0.9692	0.7026	0.9598
93	0.8207	0.6373	0.9695	0.7031	0.9617
94	0.8228	0.6382	0.9707	0.7032	0.9704
95	0.8235	0.6416	0.9721	0.7035	0.9717
96	0.8240	0.6428	0.9746	0.7065	0.9730
97	0.8258	0.6424	0.9747	0.7070	0.9745
98	0.8271	0.6429	0.9751	0.7099	0.9767
99	0.8294	0.6455	0.9754	0.7099	0.9783
100	0.8334	0.6491	0.9764	0.7144	0.9821
101	0.8352	0.6536	0.9769	0.7149	0.9821
102	0.8368	0.6556	0.9792	0.7153	0.9860
103	0.8381	0.6596	0.9937	0.7170	0.9886
104	0.8399	0.6597	0.9945	0.7178	0.9900
105	0.8476	0.6603	0.9958	0.7181	0.9923
106	0.8500	0.6624	0.9961	0.7205	0.9934
107	0.8518	0.6669	0.9963	0.7214	0.9945
108	0.8523	0.6675	0.9964	0.7226	0.9955
109	0.8565	0.6726	0.9970	0.7234	0.9962
110	0.8574	0.6798	0.9970	0.7246	0.9983
111	0.8580	0.6799	0.9978	0.7254	0.9996
112	0.8588	0.6806	0.9980	0.7260	1.0006
113	0.8624	0.6833	0.9989	0.7271	1.0071
114	0.8664	0.6838	0.9993	0.7282	1.0083
115	0.8665	0.6848	1.0033	0.7302	1.0084
116	0.8667	0.6911	1.0033	0.7317	1.0120
117	0.8685	0.6945	1.0045	0.7340	1.0137
118	0.8736	0.6997	1.0052	0.7341	1.0145
119	0.8811	0.7031	1.0070	0.7342	1.0172
120	0.8839	0.7036	1.0102	0.7370	1.0211
121	0.8876	0.7082	1.0103	0.7386	1.0212
122	0.8887	0.7104	1.0107	0.7412	1.0213

	M1	M2	M3	M4	M5
123	0.8909	0.7117	1.0150	0.7414	1.0241
124	0.8925	0.7122	1.0151	0.7516	1.0281
125	0.8934	0.7125	1.0160	0.7420	1.0294
126	0.8955	0.7240	1.0186	0.7422	1.0300
127	0.9001	0.7270	1.0186	0.7426	1.0377
128	0.9015	0.7341	1.0207	0.7440	1.0387
129	0.9016	0.7490	1.0244	0.7446	1.0397
130	0.9127		1.0253	0.7483	1.0443
131	0.9275		1.0267	0.7507	1.0444
132	0.9314		1.0274	0.7523	1.0444
133	0.9335		1.0283	0.7531	1.0461
134	0.9349		1.0331	0.7541	1.0462
135	0.9447		1.0348	0.7610	1.0525
136	0.9542		1.0354	0.7639	1.0530
137			1.0360	0.7640	1.0554
138			1.0361	0.7641	1.0573
139			1.0413	0.7652	1.0630
140			1.0416	0.7658	1.0647
141			1.0451	0.7660	1.0654
142			1.0452	0.7665	1.0758
143			1.0467	0.7672	1.0803
144			1.0547	0.7688	1.0842
145			1.0614	0.7703	1.0856
146			1.0688	0.7707	1.0972
147			1.0692	0.7746	1.1017
148			1.0693	0.7751	1.1096
149			1.0761	0.7769	1.1154
150			1.0804	0.7769	1.1647
151			1.0867	0.7776	1.1708
152			1.0868	0.7786	
153			1.0893	0.7816	
154			1.0923	0.7831	
155			1.0939	0.7866	
156			1.0954	0.7874	
157			1.1110	0.7931	
158			1.1120	0.7958	
159			1.1124	0.7958	
160			1.1137	0.7971	
161			1.1202	0.7982	
162			1.1210	0.8011	
163			1.1219	0.8021	
164			1.1223	0.8036	
165			1.1233	0.8085	
166			1.1323	0.8193	
167			1.1325	0.8242	
168			1.1330	0.8279	
169			1.1363	0.8286	
170			1.1365	0.8303	
171			1.1585	0.8325	
172			1.1610	0.8340	
173			1.1812	0.8355	
174			1.1863	0.8355	
175			1.1899	0.8476	
176			1.2145	0.8595	
177			1.2368	0.8700	
178				0.8781	
179				0.8935	

Achene weight (in mg) for Initial Material, Location S.

	S1	S2	S3	S4	S5
1	0.1029	0.1177	0.0911	0.1252	0.0096
2	0.1034	0.1277	0.0938	0.1279	0.1082
3	0.1035	0.1328	0.0939	0.1303	0.1118
4	0.1101	0.1347	0.0989	0.1315	0.1143
5	0.1102	0.1377	0.0989	0.1317	0.1173
6	0.1138	0.1380	0.0995	0.1347	0.1210
7	0.1143	0.1549	0.1110	0.2511	0.1236
8	0.1163	0.1554	0.1207	0.2531	0.1385
9	0.1316	0.1633	0.1249	0.2632	0.1704
10	0.2685	0.1654	0.1304	0.2883	0.1809
11	0.2690	0.2108	0.2347	0.2921	0.1995
12	0.2734	0.2436	0.2560	0.2978	0.2047
13	0.2802	0.2646	0.2741	0.3037	0.2500
14	0.2878	0.2913	0.2771	0.3077	0.2844
15	0.2890	0.2976	0.2818	0.3091	0.2918
16	0.2964	0.3168	0.2972	0.3134	0.2933
17	0.2966	0.3208	0.2996	0.3138	0.2972
18	0.2999	0.3400	0.3044	0.3169	0.3009
19	0.3039	0.3449	0.3125	0.3304	0.3074
20	0.3042	0.3570	0.3141	0.3360	0.3125
21	0.3045	0.3591	0.3490	0.3451	0.3179
22	0.3112	0.3595	0.3775	0.3992	0.3190
23	0.3115	0.3646	0.4344	0.4194	0.3191
24	0.3115	0.3692	0.4598	0.4455	0.3197
25	0.3189	0.3724	0.4829	0.4721	0.3242
26	0.3196	0.3767	0.4833	0.4737	0.3282
27	0.3198	0.3781	0.4842	0.4809	0.3296
28	0.3210	0.3793	0.4854	0.4865	0.3440
29	0.3218	0.3870	0.4929	0.4909	0.3971
30	0.3220	0.3882	0.4994	0.4991	0.3999
31	0.3284	0.3926	0.5064	0.5382	0.4019
32	0.3312	0.4036	0.5249	0.5396	0.4129
33	0.3340	0.4041	0.5289	0.5482	0.4183
34	0.3417	0.4074	0.5506	0.5548	0.4235
35	0.3517	0.4122	0.5507	0.5668	0.4368
36	0.3555	0.4122	0.5559	0.5671	0.4643
37	0.3584	0.4130	0.5561	0.5811	0.4842
38	0.3652	0.4159	0.5595	0.5852	0.5074
39	0.3855	0.4183	0.5822	0.5879	0.5113
40	0.3921	0.4204	0.5879	0.5903	0.5141
41	0.4249	0.4217	0.5950	0.5981	0.5196
42	0.4625	0.4369	0.5985	0.6076	0.5211
43	0.4724	0.4402	0.6124	0.6193	0.5249
44	0.4819	0.4404	0.6224	0.6203	0.5294
45	0.5139	0.4502	0.6347	0.6209	0.5300
46	0.5824	0.4558	0.6464	0.6214	0.5317
47	0.5960	0.4581	0.6473	0.6228	0.5436
48	0.6020	0.4739	0.6484	0.6326	0.5556
49	0.6148	0.4727	0.6722	0.6336	0.5581
50	0.6149	0.4742	0.6739	0.6378	0.5596
51	0.6196	0.4801	0.6932	0.6477	0.5606
52	0.6338	0.4897	0.7065	0.6504	0.5700
53	0.6428	0.4935	0.7126	0.6510	0.5716
54	0.6460	0.4946	0.7129	0.6559	0.5727
55	0.6528	0.5164	0.7147	0.6613	0.5731
56	0.6605	0.5175	0.7154	0.6625	0.5751
57	0.6614	0.5189	0.7170	0.6696	0.5784
58	0.6639	0.5204	0.7212	0.6734	0.5812
59	0.6710	0.5305	0.7283	0.6743	0.5944
60	0.6852	0.5465	0.7365	0.6846	0.5950
61	0.7038	0.5531	0.7395	0.6862	0.6027

	S1	S2	S3	S4	S5
62	0.7093	0.5621	0.7421	0.6967	0.6129
63	0.7100	0.5627	0.7441	0.6968	0.6138
64	0.7107	0.5684	0.7461	0.6990	0.6150
65	0.7140	0.5689	0.7543	0.6993	0.6155
66	0.7151	0.5690	0.7548	0.8023	0.6190
67	0.7222	0.5722	0.7610	0.7027	0.6251
68	0.7283	0.5805	0.7725	0.7044	0.6261
69	0.7337	0.5982	0.7850	0.7111	0.6281
70	0.7357	0.6016	0.7869	0.7186	0.6282
71	0.7443	0.6045	0.7894	0.7197	0.6306
72	0.7662	0.6087	0.7901	0.7251	0.6310
73	0.7671	0.6090	0.7917	0.7274	0.6313
74	0.7679	0.6149	0.7928	0.7285	0.6328
75	0.7701	0.6177	0.7949	0.7287	0.6343
76	0.7757	0.6190	0.8008	0.7292	0.6368
77	0.7766	0.6303	0.8113	0.7331	0.6377
78	0.7787	0.6384	0.8121	0.7333	0.6383
79	0.7787	0.6466	0.8127	0.7339	0.6411
80	0.7790	0.6547	0.8157	0.7425	0.6432
81	0.7800	0.6684	0.8172	0.7436	0.6467
82	0.7852	0.6745	0.8192	0.7468	0.6479
83	0.7858	0.6877	0.8195	0.7529	0.6512
84	0.7871	0.6964	0.8216	0.7555	0.6527
85	0.7875	0.6970	0.8226	0.7596	0.6536
86	0.7913	0.6990	0.8257	0.7616	0.6558
87	0.7932	0.7049	0.8306	0.7651	0.6563
88	0.7971	0.7204	0.8311	0.7655	0.6566
89	0.8023	0.7226	0.8312	0.7670	0.6594
90	0.8029	0.7256	0.8357	0.7757	0.6606
91	0.8272	0.7442	0.8378	0.7797	0.6607
92	0.8286	0.7460	0.8393	0.7802	0.6620
93	0.8324	0.7497	0.8427	0.7864	0.6621
94	0.8366	0.7625	0.8430	0.7890	0.6628
95	0.8381	0.7721	0.8451	0.7970	0.6664
96	0.8415	0.7749	0.8452	0.7979	0.6678
97	0.8419	0.7779	0.8453	0.8010	0.6685
98	0.8440	0.7822	0.8453	0.8019	0.6686
99	0.8508	0.7865	0.8455	0.8068	0.6686
100	0.8524	0.7936	0.8462	0.8114	0.6712
101	0.8528	0.7995	0.8678	0.8192	0.6736
102	0.8530	0.8018	0.8496	0.8221	0.6754
103	0.8532	0.8058	0.8505	0.8226	0.6794
104	0.8534	0.8227	0.8519	0.8274	0.6814
105	0.8558	0.8240	0.8542	0.8294	0.6819
106	0.8564	0.8275	0.8574	0.8315	0.6826
107	0.8604	0.8305	0.8589	0.8345	0.6860
108	0.8604	0.8365	0.8599	0.8352	0.6872
109	0.8651	0.8466	0.8618	0.8360	0.6888
110	0.8660	0.8627	0.8618	0.8388	0.6903
111	0.8688	0.8654	0.8669	0.8395	0.6909
112	0.8710	0.8702	0.8680	0.8396	0.6911
113	0.8724	0.8790	0.8681	0.8436	0.6985
114	0.8762	0.8851	0.8681	0.8474	0.7030
115	0.8763	0.8864	0.8690	0.8612	0.7034
116	0.8773	0.8865	0.8697	0.8619	0.7057
117	0.8791	0.8877	0.8719	0.8633	0.7058
118	0.8795	0.8907	0.8740	0.8658	0.7082
119	0.8799	0.8908	0.8754	0.8759	0.7093
120	0.8833	0.8952	0.8795	0.8774	0.7131
121	0.8851	0.8955	0.8798	0.8817	0.7159
122	0.8859	0.8986	0.8833	0.8885	0.7262

	S1	S2	S3	S4	S5
123	0.8863	0.9011	0.8834	0.8890	0.7267
124	0.8884	0.9027	0.8868	0.8899	0.7272
125	0.8891	0.9055	0.8849	0.8915	0.7272
126	0.8894	0.9089	0.8909	0.8944	0.7275
127	0.8916	0.9134	0.8936	0.8948	0.7344
128	0.8938	0.9157	0.8964	0.8971	0.7351
129	0.8941	0.9198	0.8969	0.8982	0.7381
130	0.8956	0.9221	0.8988	0.8998	0.7414
131	0.8959	0.9237	0.8989	0.9010	0.7419
132	0.8963	0.9266	0.9000	0.9027	0.7464
133	0.8964	0.9335	0.9002	0.9079	0.7470
134	0.8976	0.9432	0.9014	0.9091	0.7579
135	0.9034	0.9451	0.9018	0.9093	0.7584
136	0.9041	0.9503	0.9028	0.9105	0.7600
137	0.9065	0.9543	0.9038	0.9109	0.7622
138	0.9069	0.9545	0.9058	0.9124	0.7638
139	0.9073	0.9692	0.9060	0.9149	0.7655
140	0.9079	0.9850	0.9081	0.9159	0.7660
141	0.9137	0.9888	0.9081	0.9165	0.7695
142	0.9157	0.9896	0.9086	0.9169	0.7708
143	0.9160	0.9904	0.9108	0.9270	0.7733
144	0.9178	0.9911	0.9114	0.9279	0.7753
145	0.9178	0.9936	0.9127	0.9283	0.7778
146	0.9181	0.9947	0.9133	0.9285	0.7783
147	0.9190	0.9972	0.9146	0.9328	0.7800
148	0.9194	1.0007	0.9151	0.9339	0.7806
149	0.9206	1.0094	0.9176	0.9339	0.7810
150	0.9217	1.0158	0.9188	0.9367	0.7851
151	0.9234	1.0217	0.9188	0.9384	0.7852
152	0.9241	1.0229	0.9194	0.9394	0.7866
153	0.9266	1.0260	0.9209	0.9406	0.7875
154	0.9268	1.0262	0.9211	0.9455	0.7875
155	0.9268	1.0282	0.9215	0.9465	0.7907
156	0.9270	1.0283	0.9217	0.9478	0.7922
157	0.9271	1.0284	0.9221	0.9496	0.7950
158	0.9284	1.0315	0.9223	0.9506	0.7986
159	0.9313	1.0340	0.9247	0.9530	0.7997
160	0.9317	1.0366	0.9265	0.9533	0.8001
161	0.9342	1.0367	0.9273	0.9536	0.8031
162	0.9344	1.0367	0.9283	0.9546	0.8039
163	0.9358	1.0406	0.9290	0.9569	0.8043
164	0.9361	1.0427	0.9294	0.9601	0.8064
165	0.9365	1.0464	0.9305	0.9639	0.8104
166	0.9382	1.0481	0.9313	0.9387	0.8125
167	0.9383	1.0487	0.9317	0.9694	0.8136
168	0.9386	1.0536	0.9332	0.9695	0.8138
169	0.9386	1.0645	0.9335	0.9714	0.8164
170	0.9390	1.0655	0.9354	0.9731	0.8165
171	0.9415	1.0666	0.9371	0.9766	0.8166
172	0.9421	1.0692	0.9374	0.9819	0.8226
173	0.9442	1.0741	0.9397	0.9838	0.8232
174	0.9452	1.0767	0.9403	0.9843	0.8249
175	0.9472	1.0802	0.9440	0.9900	0.8265
176	0.9482	1.0810	0.9447	0.9906	0.8304
177	0.9492	1.0932	0.9453	0.9909	0.8306
178	0.9496	1.0953	0.9465	1.0035	0.8337
179	0.9498	1.1060	0.9478	1.0089	0.8337
180	0.9519	1.1098	0.9480	1.0152	0.8375
181	0.9522	1.1139	0.9492	1.0264	0.8410
182	0.9525	1.1172	0.9497	1.0273	0.8411
183	0.9525	1.1194	0.9519	1.0310	0.8459

	S1	S2	S3	S4	S5
184	0.9539	1.1194	0.9528	1.0360	0.8487
185	0.9553	1.1195	0.9592	1.0371	0.8525
186	0.9573	1.1244	0.9594	1.0632	0.8640
187	0.9629	1.1402	0.9648	1.0675	0.8640
188	0.9629	1.1405	0.9652	1.0683	0.8640
189	0.9633	1.1469	0.9676	1.0700	0.8660
190	0.9657	1.1479	0.9717	1.0768	0.8707
191	0.9664	1.1529	0.9732	1.0771	0.8738
192	0.9679	1.1547	0.9750	1.0789	0.8743
193	0.9679	1.1561	0.9756	1.1048	0.8743
194	0.9705	1.1575	0.9779	1.1062	0.8744
195	0.9715	1.1580	0.9804	1.1161	0.8772
196	0.9716	1.1629	0.9812	1.1172	0.8773
197	0.9717	1.1634	0.9821	1.1236	0.8801
198	0.9721	1.1703	0.9852	1.1766	0.8861
199	0.9747	1.1952	0.9878	1.4406	0.8883
200	0.9758	1.1982	0.9879		0.8913
201	0.9778	1.2089	0.9891		0.8961
202	0.9807	1.2255	0.9928		0.8963
203	0.9808	1.2259	0.9958		0.9003
204	0.9827	1.2307	1.0028		0.9024
205	0.9828	1.2402	1.0031		0.9049
206	0.9846	1.2735	1.0037		0.9060
207	0.9884	1.2794	1.0084		0.9124
208	0.9895	1.3116	1.0094		0.9134
209	0.9897		1.0164		0.9290
210	0.9921		1.0171		0.9334
211	0.9933		1.0250		0.9343
212	0.9940		1.0292		0.9373
213	0.9941		1.0312		0.9447
214	0.9943		1.0500		0.9488
215	0.9950				
216	0.9955				
217	0.9986				
218	1.0025				
219	1.0045				
220	1.0056				
221	1.0078				
222	1.0110				
223	1.0126				
224	1.0146				
225	1.0193				
226	1.0196				
227	1.0206				
228	1.0215				
229	1.0226				
230	1.0239				
231	1.0318				
232	1.0337				
233	1.0359				
234	1.0428				
235	1.0461				
236	1.0787				
237	1,0872				
238	1.0891				
239	1.0907				
240	1.0996				
241	1.1023				
242	1.1148				
243	1.1654				

Appendix I b M1 Achene Dissection (wt in mg)

	ach wt	coat wt	embro wt	tl dwt
1	0.361	0.170	0.180	0.350
2	0.566	0.268	0.239	0.507
3	0.590	0.252	0.260	0.512
4	0.608	0.238	0.168	0.406
5	0.609	0.257	0.286	0.543
6	0.612	0.280	0.286	0.566
7	0.623	0.236	0.104	0.340
8	0.629	0.393	0.100	0.493
9	0.645	0.284	0.309	0.593
10	0.653	0.344	0.197	0.541
11	0.658	0.328	0.171	0.499
12	0.672	0.274	0.359	0.633
13	0.673	0.252	0.225	0.477
14	0.673	0.304	0.242	0.546
15	0.674	0.277	0.241	0.518
16	0.675	0.214	0.372	0.586
17	0.677	0.266	0.288	0.554
18	0.680	0.246	0.317	0.563
19	0.684	0.255	0.365	0.620
20	0.684	0.287	0.351	0.638
21	0.686	0.367	0.325	0.692
22	0.693	0.272	0.338	0.610
23	0.693	0.262	0.286	0.548
24	0.698	0.312	0.336	0.648
25	0.702	0.300	0.293	0.593
26	0.703	0.301	0.362	0.663
27	0.711	0.272	0.305	0.577
28	0.714	0.525	0.092	0.617
29	0.715	0.303	0.200	0.503
30	0.721	0.237	0.340	0.577
31	0.722	0.270	0.247	0.517
32	0.722	0.297	0.084	0.381
33	0.730	0.296	0.249	0.545
34	0.731	0.306	0.317	0.623
35	0.734	0.283	0.350	0.633
36	0.734	0.291	0.436	0.727
37	0.734	0.263	0.329	0.592
38	0.734	0.313	0.374	0.687
39	0.734	0.280	0.295	0.575
40	0.739	0.270	0.310	0.580
41	0.740	0.314	0.354	0.668
42	0.740	0.299	0.418	0.717
43	0.742	0.309	0.252	0.561
44	0.752	0.306	0.419	0.725
45	0.753	0.306	0.396	0.702
46	0.755	0.279	0.377	0.656
47	0.766	0.285	0.381	0.666
48	0.768	0.270	0.195	0.465
49	0.768	0.315	0.417	0.732
50	0.770	0.275	0.451	0.726
51	0.771	0.345	0.404	0.749
52	0.773	0.377	0.345	0.722
53	0.774	0.309	0.427	0.736
54	0.778	0.304	0.413	0.717
55	0.779	0.361	0.353	0.714
56	0.781	0.571	0.132	0.703
57	0.782	0.314	0.295	0.609
58	0.783	0.312	0.411	0.723
59	0.783	0.340	0.377	0.717
60	0.784	0.285	0.457	0.742
61	0.790	0.291	0.433	0.724
62	0.790	0.282	0.418	0.700
63	0.793	0.323	0.400	0.723
64	0.804	0.331	0.386	0.717
65	0.806	0.308	0.337	0.645
66	0.806	0.272	0.364	0.636
67	0.812	0.311	0.434	0.745
68	0.821	0.392	0.392	0.784
69	0.823	0.301	0.488	0.789
70	0.824	0.308	0.502	0.810
71	0.828	0.325	0.395	0.720
72	0.854	0.302	0.482	0.784
73	0.863	0.319	0.469	0.788
74	0.877	0.315	0.526	0.841
75	1.003	0.506	0.277	0.783
76	1.146	0.482	0.624	1.106
77	1.151	0.500	0.633	1.133
78	1.153	0.512	0.498	1.010
79	1.192	0.459	0.657	1.116
80	1.200	0.522	0.586	1.108
81	1.202	0.500	0.641	1.141
82	1.215	0.408	0.765	1.173
83	1.248	0.472	0.634	1.106
84	1.250	0.493	0.724	1.217
85	1.273	0.578	0.516	1.094
86	1.273	0.524	0.632	1.156
87	1.275	0.531	0.700	1.231
88	1.320	0.402	0.827	1.229
89	1.341	0.539	0.710	1.249
90	1.342	0.593	0.600	1.193
91	1.384	0.640	0.543	1.183
92	1.388	0.577	0.658	1.235
93	1.424	0.529	0.805	1.334
94	1.429	0.555	0.779	1.334
95	1.453	0.588	0.808	1.396
96	1.455	0.567	0.796	1.363
97	1.485	0.528	0.911	1.439

M2 Achene Dissection (wt in mg)

	ach wt	coat wt	embro wt	tl dwt
1	0.239	0.173	0.045	0.218
2	0.274	0.176	0.078	0.254
3	0.337	0.254	0.035	0.289
4	0.339	0.218	0.056	0.274
5	0.349	0.202	0.099	0.301
6	0.379	0.255	0.092	0.347
7	0.419	0.296	0.111	0.407
8	0.424	0.223	0.137	0.376
9	0.428	0.215	0.156	0.371
10	0.450	0.217	0.149	0.366
11	0.455	0.227	0.132	0.359
12	0.465	0.297	0.100	0.397
13	0.470	0.325	0.134	0.459
14	0.473	0.210	0.179	0.389
15	0.482	0.219	0.065	0.284
16	0.484	0.319	0.095	0.414
17	0.484	0.322	0.103	0.425
18	0.493	0.205	0.276	0.481
19	0.495	0.261	0.184	0.445
20	0.503	0.154	0.263	0.417
21	0.522	0.216	0.209	0.425
22	0.533	0.333	0.172	0.505
23	0.535	0.240	0.253	0.493
24	0.536	0.231	0.165	0.396
25	0.542	0.230	0.211	0.441
26	0.542	0.218	0.189	0.407
27	0.545	0.372	0.027	0.399
28	0.549	0.235	0.262	0.497
29	0.551	0.221	0.312	0.533
30	0.552	0.221	0.258	0.479
31	0.561	0.237	0.203	0.440
32	0.561	0.289	0.131	0.420
33	0.564	0.143	0.243	0.386
34	0.567	0.235	0.216	0.451
35	0.568	0.283	0.260	0.543
36	0.570	0.254	0.236	0.490
37	0.572	0.265	0.249	0.514
38	0.573	0.312	0.183	0.495
39	0.575	0.275	0.254	0.529
40	0.583	0.333	0.304	0.637
41	0.591	0.299	0.269	0.568
42	0.591	0.256	0.226	0.482
43	0.591	0.287	0.163	0.450
44	0.594	0.421	0.124	0.545
45	0.597	0.245	0.203	0.448
46	0.600	0.348	0.200	0.548
47	0.605	0.300	0.201	0.501
48	0.608	0.265	0.261	0.526
49	0.609	0.242	0.258	0.500
50	0.613	0.313	0.282	0.595
51	0.616	0.291	0.246	0.537
52	0.627	0.267	0.245	0.512
53	0.632	0.270	0.333	0.603
54	0.638	0.391	0.220	0.611
55	0.642	0.295	0.326	0.621
56	0.650	0.338	0.264	0.602
57	0.651	0.246	0.261	0.507
58	0.652	0.280	0.305	0.585
59	0.654	0.259	0.263	0.522
60	0.655	0.287	0.368	0.655
61	0.656	0.271	0.343	0.614
62	0.666	0.369	0.256	0.625
63	0.669	0.317	0.164	0.481
64	0.674	0.261	0.355	0.616
65	0.676	0.346	0.253	0.599
66	0.682	0.245	0.373	0.618
67	0.683	0.270	0.363	0.633
68	0.687	0.303	0.262	0.565
69	0.694	0.375	0.081	0.456
70	0.701	0.276	0.401	0.677
71	0.709	0.294	0.345	0.639
72	0.720	0.393	0.196	0.589
73	0.722	0.287	0.383	0.670
74	0.732	0.355	0.234	0.589
75	0.737	0.291	0.364	0.655
76	0.738	0.329	0.356	0.685
77	0.766	0.341	0.345	0.686
78	0.775	0.324	0.347	0.671
79	0.778	0.394	0.313	0.707
80	0.791	0.366	0.383	0.749
81	0.796	0.365	0.398	0.763
82	0.796	0.358	0.298	0.656
83	0.802	0.384	0.384	0.768
84	0.814	0.355	0.403	0.758
85	0.816	0.291	0.477	0.768
86	0.817	0.365	0.396	0.761
87	0.824	0.364	0.404	0.768
88	0.829	0.402	0.419	0.821
89	0.853	0.383	0.372	0.755
90	0.878	0.385	0.415	0.800
91	0.892	0.394	0.421	0.815
92	0.913	0.423	0.325	0.748
93	0.932	0.388	0.493	0.881
94	0.959	0.613	0.307	0.920

W1 Achene Dissection (wt in mg)

	ach wt	coat wt	embro wt	tl dwt
1	0.2295	0.1328	0.0235	0.1563
2	0.2663	0.1941	0.0308	0.2249
3	0.2664	0.1950	0.0429	0.2379
4	0.2677	0.1130	0.0909	0.2039
5	0.2835	0.2237	0.0284	0.2521
6	0.2882	0.2135	0.0071	0.2206
7	0.3037	0.2008	0.0842	0.2850
8	0.3082	0.2001	0.0572	0.2573
9	0.3141	0.2289	0.0165	0.2454
10	0.3149	0.1959	0.0102	0.2061
11	0.3232	0.2471	0.0257	0.2728
12	0.3327	0.2605	0.0111	0.2716
13	0.3341	0.2076	0.0215	0.2291
14	0.3344	0.2226	0.0358	0.2584
15	0.3392	0.2460	0.0701	0.3161
16	0.3425	0.2330	0.0599	0.2929
17	0.3427	0.2200	0.0671	0.2871
18	0.3459	0.2233	0.0465	0.2698
19	0.3469	0.2226	0.0881	0.3107
20	0.3476	0.2034	0.0997	0.3031
21	0.3498	0.2027	0.1142	0.3169
22	0.3523	0.2407	0.0493	0.2900
23	0.3561	0.2455	0.0548	0.3003
24	0.3644	0.2467	0.0862	0.3329
25	0.3651	0.1746	0.1688	0.3434
26	0.3660	0.2461	0.0903	0.3364
27	0.3701	0.2403	0.0927	0.3330
28	0.3941	0.2411	0.1014	0.3425
29	0.3954	0.2419	0.0920	0.3339
30	0.4079	0.2193	0.0789	0.2982
31	0.4163	0.2124	0.1791	0.3915
32	0.4245	0.2928	0.0710	0.3638
33	0.4251	0.2696	0.1238	0.3934
34	0.4281	0.2851	0.0838	0.3689
35	0.4295	0.2788	0.0919	0.3707
36	0.4362	0.2442	0.1380	0.3822
37	0.4384	0.2608	0.1337	0.3945
38	0.4399	0.2275	0.1795	0.4070
39	0.4441	0.2649	0.1290	0.3939
40	0.4545	0.2759	0.1244	0.4003
41	0.4575	0.2063	0.1815	0.3878
42	0.4644	0.2560	0.1231	0.3791
43	0.4769	0.1180	0.1677	0.2857
44	0.4839	0.2688	0.1288	0.3976
45	0.4871	0.3574	0.0569	0.4143
46	0.4983	0.2670	0.1373	0.4043
47	0.5186	0.1770	0.2145	0.3915
48	0.5245	0.4145	0.0325	0.4470
49	0.5346	0.2729	0.1742	0.4471
50	0.5361	0.3093	0.1198	0.4291
51	0.5381	0.2234	0.2519	0.4753
52	0.5401	0.3411	0.1429	0.4840
53	0.5545	0.2708	0.2187	0.4895
54	0.5628	0.2928	0.2150	0.5078
55	0.5707	0.2846	0.1927	0.4773
56	0.5793	0.2856	0.2250	0.5106
57	0.5831	0.2943	0.1012	0.3955
58	0.5935	0.3059	0.1270	0.4329
59	0.6043	0.4094	0.1508	0.5602
60	0.6473	0.3316	0.0959	0.4275
61	0.6632	0.3172	0.2304	0.5476
62	0.6775	0.3218	0.1331	0.4549
63	0.6778	0.3380	0.1814	0.5194
64	0.6833	0.2919	0.2911	0.5830
65	0.6914	0.2969	0.2290	0.5259
66	0.6931	0.3159	0.3309	0.6468
67	0.6987	0.3550	0.2998	0.6548
68	0.7183	0.2846	0.3944	0.6790
69	0.7221	0.3108	0.2874	0.5982
70	0.7402	0.2828	0.2524	0.5352
71	0.7731	0.3032	0.2586	0.5618
72	0.7779	0.3182	0.3707	0.6889
73	0.7802	0.4419	0.2198	0.6617
74	0.8034	0.3776	0.2953	0.6729
75	0.8084	0.2143	0.5417	0.7560
76	0.8382	0.6817	0.0643	0.7460
77	0.8418	0.2057	0.3027	0.5084
78	0.8515	0.3007	0.4682	0.7689
79	0.8537	0.4723	0.2372	0.7095
80	0.8578	0.2931	0.4775	0.7706
81	0.8647	0.3390	0.4683	0.8073
82	0.8748	0.3119	0.3852	0.6971
83	0.8775	0.3859	0.3336	0.7195
84	0.8905	0.5355	0.2439	0.7794
85	0.8922	0.2901	0.5339	0.8240
86	0.8966	0.3149	0.5136	0.8285
87	0.9006	0.2861	0.5221	0.8082
88	0.9019	0.3274	0.5426	0.8700
89	0.9082	0.3057	0.4001	0.7058
90	0.9111	0.3350	0.4515	0.7865
91	0.9175	0.3513	0.4613	0.8126
92	0.9265	0.3601	0.4659	0.8260
93	0.9333	0.3459	0.4811	0.8270
94	0.9357	0.3088	0.4164	0.7252
95	0.9362	0.3300	0.5387	0.8687
96	0.9362	0.5086	0.2690	0.7776
97	0.9498	0.4341	0.3373	0.7714
98	0.9501	0.2499	0.4395	0.6894
99	0.9568	0.3359	0.4460	0.7819
100	0.9793	0.5278	0.3648	0.8926
101	0.9838	0.6842	0.2131	0.8973
102	1.0072	0.4825	0.3852	0.8677
103	1.0130	0.3238	0.6278	0.9516
104	1.0455	0.3299	0.5938	0.9237
105	1.0464	0.3414	0.5989	0.9403
106	1.0762	0.3489	0.6892	1.0381

W3 Achene Dissection (wt in mg)

	ach wt	coat wt	embro wt	tldwt
1	0.2373	0.1830	0.0046	0.1876
2	0.2434	0.1819	0.0124	0.1943
3	0.2529	0.1802	0.0036	0.1838
4	0.2536	0.1849	0.0085	0.1934
5	0.2746	0.1641	0.0960	0.2601
6	0.2800	0.2043	0.0364	0.2407
7	0.2973	0.1845	0.0309	0.2154
8	0.3046	0.2142	0.0176	0.2318
9	0.3133	0.1643	0.0982	0.2625
10	0.3151	0.1849	0.0783	0.2632
11	0.3343	0.1693	0.1470	0.3163
12	0.3438	0.0750	0.1695	0.2445
13	0.3648	0.1677	0.0205	0.1882
14	0.3680	0.1695	0.0936	0.2631
15	0.3753	0.2186	0.1021	0.3207
16	0.3763	0.2101	0.0986	0.3087
17	0.3850	0.1645	0.2111	0.3756
18	0.3927	0.1736	0.1786	0.3522
19	0.4015	0.1640	0.2177	0.3817
20	0.4027	0.1703	0.2196	0.3899
21	0.4092	0.2793	0.0594	0.3387
22	0.4096	0.2110	0.1795	0.3905
23	0.4108	0.2333	0.0947	0.3280
24	0.4248	0.2211	0.1274	0.3485
25	0.4281	0.2048	0.1361	0.3409
26	0.4293	0.2064	0.2075	0.4139
27	0.4338	0.2058	0.1743	0.3801
28	0.4427	0.2301	0.1898	0.4199
29	0.4454	0.1953	0.0656	0.2609
30	0.4481	0.1660	0.1512	0.3172
31	0.4613	0.2537	0.1706	0.4243
32	0.4766	0.1760	0.2385	0.4145
33	0.4770	0.1593	0.2875	0.4468
34	0.4816	0.2251	0.1226	0.3477
35	0.4913	0.1787	0.1267	0.3054
36	0.5005	0.2393	0.2358	0.4751
37	0.5045	0.2080	0.1547	0.3627
38	0.5052	0.2367	0.2094	0.4461
39	0.5236	0.2320	0.2464	0.4784
40	0.5274	0.2132	0.1975	0.4107
41	0.5395	0.2205	0.2728	0.4933
42	0.5407	0.1979	0.3926	0.5905
43	0.5432	0.1999	0.2433	0.4432
44	0.5437	0.1397	0.1790	0.3187
45	0.5438	0.1976	0.2746	0.4722
46	0.5466	0.2445	0.1863	0.4308
47	0.5495	0.2155	0.1577	0.3732
48	0.5542	0.2215	0.1881	0.4096
49	0.5551	0.1993	0.2468	0.4461
50	0.5554	0.2146	0.1301	0.3447
51	0.5569	0.2374	0.2075	0.4449
52	0.5620	0.2020	0.2599	0.4619
53	0.5621	0.2529	0.1737	0.4266
54	0.5777	0.2603	0.2535	0.5038
55	0.5825	0.2360	0.2533	0.4893
56	0.5868	0.2427	0.2967	0.5394
57	0.5876	0.2126	0.3242	0.5368
58	0.5899	0.2475	0.2382	0.4857
59	0.5971	0.2245	0.3297	0.5542
60	0.5996	0.2143	0.2199	0.4342
61	0.6019	0.2614	0.2261	0.4875
62	0.6090	0.2277	0.3334	0.5611
63	0.6179	0.2584	0.2531	0.5115
64	0.6221	0.2173	0.3188	0.5361
65	0.6235	0.2424	0.2918	0.5342
66	0.6301	0.2194	0.3530	0.5724
67	0.6307	0.2735	0.3378	0.6113
68	0.6350	0.2387	0.3321	0.5708
69	0.6354	0.2441	0.3279	0.5720
70	0.6388	0.1927	0.4073	0.6000
71	0.6398	0.1772	0.4367	0.6139
72	0.6480	0.2480	0.3676	0.6156
73	0.6488	0.2553	0.3608	0.6161
74	0.6495	0.2406	0.3749	0.6155
75	0.6523	0.2272	0.3931	0.6203
76	0.6531	0.2557	0.3263	0.5820
77	0.6541	0.2525	0.3741	0.6266
78	0.6556	0.2472	0.3569	0.6041
79	0.6583	0.1719	0.3894	0.5613
80	0.6587	0.2339	0.3489	0.5828
81	0.6592	0.1871	0.4080	0.5951
82	0.6612	0.2472	0.3609	0.6081
83	0.6706	0.2420	0.4031	0.6451
84	0.6714	0.2552	0.3659	0.6211
85	0.6751	0.1493	0.3455	0.4948
86	0.6769	0.2534	0.3207	0.5741
87	0.6846	0.2360	0.4065	0.6425
88	0.6924	0.2662	0.2985	0.5647
89	0.6930	0.2482	0.3426	0.5908
90	0.6972	0.2814	0.3959	0.6773
91	0.6999	0.2390	0.4370	0.6760
92	0.7012	0.2572	0.4211	0.6783
93	0.7258	0.2756	0.4079	0.6835
94	0.7374	0.3956	0.1618	0.5574
95	0.7453	0.2998	0.1427	0.4425
96	0.7648	0.2410	0.3972	0.6382

W5 Achene Dissection (wt in mg)

	ach wt	coat wt	embro wt	tl dwt
1	0.216	0.174	0.024	0.198
2	0.228	0.165	0.051	0.216
3	0.259	0.147	0.103	0.250
4	0.269	0.174	0.090	0.264
5	0.342	0.169	0.152	0.321
6	0.344	0.180	0.153	0.333
7	0.349	0.161	0.170	0.331
8	0.361	0.175	0.181	0.356
9	0.376	0.174	0.190	0.364
10	0.394	0.157	0.215	0.372
11	0.394	0.167	0.225	0.392
12	0.398	0.174	0.201	0.375
13	0.401	0.174	0.211	0.385
14	0.406	0.170	0.225	0.395
15	0.411	0.273	0.050	0.323
16	0.419	0.184	0.169	0.353
17	0.446	0.189	0.209	0.398
18	0.467	0.161	0.292	0.453
19	0.471	0.220	0.208	0.428
20	0.472	0.173	0.295	0.468
21	0.480	0.169	0.292	0.461
22	0.480	0.174	0.291	0.465
23	0.493	0.188	0.282	0.470
24	0.503	0.332	0.053	0.385
25	0.504	0.219	0.250	0.469
26	0.505	0.176	0.311	0.487
27	0.518	0.182	0.299	0.481
28	0.523	0.166	0.330	0.496
29	0.531	0.185	0.322	0.507
30	0.537	0.249	0.247	0.496
31	0.547	0.217	0.287	0.504
32	0.550	0.169	0.356	0.525
33	0.550	0.106	0.413	0.519
34	0.553	0.172	0.217	0.389
35	0.553	0.173	0.179	0.352
36	0.554	0.263	0.142	0.405
37	0.562	0.180	0.372	0.552
38	0.567	0.254	0.273	0.527
39	0.567	0.191	0.287	0.478
40	0.569	0.174	0.355	0.529
41	0.571	0.183	0.356	0.539
42	0.576	0.190	0.352	0.542
43	0.581	0.175	0.286	0.461
44	0.582	0.224	0.315	0.539
45	0.587	0.231	0.311	0.542
46	0.589	0.199	0.351	0.550
47	0.590	0.231	0.326	0.557
48	0.602	0.246	0.238	0.484
49	0.603	0.209	0.382	0.591
50	0.614	0.226	0.325	0.551
51	0.614	0.198	0.325	0.523
52	0.617	0.241	0.323	0.564
53	0.619	0.144	0.397	0.541
54	0.619	0.163	0.425	0.588
55	0.622	0.265	0.327	0.592
56	0.632	0.215	0.318	0.533
57	0.635	0.145	0.394	0.539
58	0.635	0.182	0.414	0.596
59	0.637	0.390	0.177	0.567
60	0.639	0.232	0.374	0.606
61	0.641	0.165	0.451	0.616
62	0.642	0.224	0.260	0.484
63	0.643	0.195	0.122	0.317
64	0.644	0.237	0.383	0.620
65	0.645	0.230	0.367	0.597
66	0.651	0.233	0.393	0.626
67	0.651	0.186	0.406	0.592
68	0.652	0.182	0.440	0.622
69	0.655	0.152	0.448	0.600
70	0.657	0.190	0.397	0.587
71	0.664	0.265	0.334	0.599
72	0.665	0.185	0.457	0.642
73	0.682	0.330	0.308	0.638
74	0.689	0.353	0.099	0.452
75	0.696	0.234	0.431	0.665
76	0.699	0.486	0.096	0.582
77	0.700	0.266	0.380	0.646
78	0.702	0.192	0.423	0.615
79	0.702	0.234	0.301	0.535
80	0.709	0.261	0.420	0.681
81	0.714	0.264	0.336	0.600
82	0.717	0.262	0.340	0.602
83	0.719	0.255	0.427	0.682
84	0.719	0.208	0.503	0.711
85	0.722	0.330	0.196	0.526
86	0.725	0.238	0.191	0.429
87	0.729	0.270	0.423	0.693
88	0.730	0.246	0.414	0.660
89	0.733	0.277	0.419	0.696
90	0.739	0.255	0.452	0.707
91	0.743	0.263	0.373	0.636
92	0.749	0.275	0.394	0.669
93	0.755	0.284	0.346	0.630
94	0.757	0.244	0.451	0.695
95	0.759	0.200	0.467	0.667
96	0.775	0.286	0.464	0.750
97	0.781	0.245	0.454	0.699
98	0.795	0.294	0.457	0.751
99	0.824	0.280	0.511	0.791

S3 Achene Dissection (wt in mg)

	ach wt	coat wt	embro wt	tl dwt
1	0.4634	0.2367	0.1976	0.4343
2	0.4721	0.1848	0.1998	0.3846
3	0.5084	0.3012	0.1233	0.4245
4	0.5205	0.2147	0.2588	0.4735
5	0.5319	0.1964	0.2072	0.4036
6	0.5717	0.2302	0.3101	0.5403
7	0.5761	0.2823	0.2219	0.5042
8	0.5903	0.2775	0.2390	0.5165
9	0.5946	0.2700	0.2279	0.4979
10	0.5996	0.2042	0.3700	0.5742
11	0.6039	0.5394	0.0321	0.5715
12	0.6061	0.2055	0.3658	0.5713
13	0.6093	0.2691	0.2454	0.5145
14	0.6121	0.2397	0.3450	0.5847
15	0.6248	0.2666	0.3047	0.5713
16	0.6282	0.2772	0.2893	0.5665
17	0.6347	0.1239	0.3412	0.4651
18	0.6362	0.2370	0.3700	0.6070
19	0.6475	0.2705	0.2952	0.5657
20	0.6497	0.2797	0.2665	0.5462
21	0.6520	0.2051	0.4015	0.6066
22	0.6558	0.2363	0.3632	0.5995
23	0.6562	0.2545	0.3609	0.6154
24	0.6585	0.2894	0.3038	0.5932
25	0.6589	0.2162	0.4039	0.6201
26	0.6639	0.1441	0.3649	0.5090
27	0.6707	0.2665	0.3670	0.6335
28	0.6748	0.2390	0.3779	0.6169
29	0.6758	0.2759	0.3635	0.6394
30	0.6786	0.2402	0.3609	0.6011
31	0.6794	0.2570	0.3535	0.6105
32	0.6880	0.2234	0.4177	0.6411
33	0.6949	0.2448	0.3609	0.6057
34	0.7022	0.2688	0.3704	0.6392
35	0.7052	0.2037	0.4713	0.6750
36	0.7090	0.2490	0.4013	0.6503
37	0.7145	0.2598	0.3389	0.5987
38	0.7178	0.2850	0.3724	0.6574
39	0.7178	0.2603	0.4085	0.6688
40	0.7200	0.2868	0.3257	0.6125
41	0.7248	0.2299	0.4825	0.7124
42	0.7265	0.2838	0.4387	0.7225
43	0.7352	0.2222	0.4336	0.6558
44	0.7362	0.2205	0.4116	0.6321
45	0.7369	0.2960	0.4069	0.7029
46	0.7418	0.2653	0.4058	0.6711
47	0.7418	0.2950	0.4448	0.7398
48	0.7441	0.2229	0.4868	0.7097
49	0.7486	0.2828	0.4166	0.6994
50	0.7505	0.2953	0.4442	0.7395
51	0.7518	0.2930	0.4049	0.6979
52	0.7520	0.3267	0.3372	0.6639
53	0.7520	0.2864	0.4316	0.7180
54	0.7559	0.2862	0.3260	0.6122
55	0.7587	0.2817	0.4244	0.7061
56	0.7604	0.2654	0.4103	0.6757
57	0.7651	0.2520	0.5207	0.7727
58	0.7659	0.2789	0.4540	0.7329
59	0.7671	0.2985	0.3428	0.6413
60	0.7682	0.2785	0.4429	0.7214
61	0.7694	0.2921	0.4400	0.7321
62	0.7713	0.3116	0.3892	0.7008
63	0.7768	0.3092	0.3719	0.6811
64	0.7781	0.2230	0.5037	0.7267
65	0.7822	0.2723	0.4742	0.7465
66	0.7875	0.2397	0.5173	0.7570
67	0.7916	0.2663	0.4099	0.6762
68	0.7984	0.2404	0.5174	0.7578
69	0.8068	0.2962	0.4865	0.7827
70	0.8159	0.2965	0.4755	0.7720
71	0.8173	0.2712	0.5075	0.7787
72	0.8234	0.3116	0.4609	0.7725
73	0.8243	0.2651	0.3461	0.6112
74	0.8301	0.2796	0.5117	0.7913
75	0.8328	0.3242	0.4741	0.7983
76	0.8356	0.2789	0.5105	0.7894
77	0.8455	0.2928	0.3704	0.6632
78	0.8488	0.2226	0.5956	0.8182
79	0.8536	0.3663	0.3115	0.6778
80	0.8571	0.3288	0.4819	0.8107
81	0.8636	0.3044	0.3304	0.6348
82	0.8653	0.2739	0.4606	0.7345
83	0.8659	0.2881	0.5068	0.7949
84	0.8660	0.2610	0.5177	0.7787
85	0.8760	0.2539	0.4274	0.6813
86	0.8764	0.3131	0.2708	0.5839
87	0.8837	0.3027	0.5301	0.8328
88	0.8912	0.3980	0.5589	0.9569
89	0.8995	0.3040	0.5266	0.8306
90	0.9034	0.3657	0.4277	0.7934
91	0.9057	0.3325	0.5165	0.8490
92	0.9105	0.2800	0.5256	0.8056
93	0.9550	0.3327	0.5365	0.8692
94	0.9799	0.3120	0.5911	0.9031
95	0.9859	0.2621	0.6933	0.9554

Appendix II a

Germination results: Months 1-8 (inclusive), 10, 12.

Month 1

	Size mg	Replicate 1 No.	Replicate 1 Germ.	Replicate 2 No.	Replicate 2 Germ.	Replicate 3 No.	Replicate 3 Germ.	Replicate 4 No.	Replicate 4 Germ.
C	To 0.3	14	4	7	1	9	2	3	2
O	0.4	21	21	12	6	14	7	4	3
N	0.5	20	20	20	19	21	11	10	9
T	0.6	18	17	18	18	24	24	16	15
R	0.7	18	18	21	21	22	22	16	16
O	0.8	4	4	33	33	8	7	18	17
L	>0.8	0	0	30	30	1	1	7	7
G	0.3	15	5	6	0	9	4	3	0
A	0.4	21	21	12	5	14	10	5	5
+	0.5	20	19	19	18	21	14	10	8
K	0.6	19	19	19	19	25	24	16	16
N	0.7	19	19	22	22	22	22	16	16
O_3	0.8	4	4	33	33	9	9	19	19
	>0.8	0	0	29	29	0	0	7	7

Month 2

	Size mg	Replicate 1 No.	Replicate 1 Germ.	Replicate 2 No.	Replicate 2 Germ.	Replicate 3 No.	Replicate 3 Germ.	Replicate 4 No.	Replicate 4 Germ.
C	To 0.3	51	2	5	0	5	0	6	1
O	0.4	31	3	6	6	3	1	11	7
N	0.5	22	9	6	6	9	8	21	18
T	0.6	6	1	14	13	21	21	16	15
R	0.7	0	0	19	19	37	36	20	12
O	0.8	0	0	24	21	23	21	35	18
L	>0.8	0	0	6	5	9	8	8	4
G	0.3	51	0	6	0	6	0	6	1
A	0.4	32	2	5	4	3	3	10	9
+	0.5	21	7	7	7	8	7	22	21
K	0.6	7	2	13	13	22	22	15	15
N	0.7	0	0	20	20	37	37	21	21
O_3	0.8	0	0	24	24	23	22	35	35
	>0.8	0	0	7	7	9	9	8	8

Month 3

	Size mg	Replicate 1 No.	Replicate 1 Germ.	Replicate 2 No.	Replicate 2 Germ.	Replicate 3 No.	Replicate 3 Germ.	Replicate 4 No.	Replicate 4 Germ.
C	To 0.3	5	0	3	2	6	0	14	4
O	0.4	16	14	7	7	14	10	9	5
N	0.5	20	20	13	13	13	12	17	17
T	0.6	16	16	13	13	21	21	22	22
R	0.7	17	17	18	18	13	13	26	26
O	0.8	23	23	10	10	23	22	35	35
L	>0.8	11	11	2	2	47	45	33	33
G	0.3	4	4	3	2	6	2	15	0
A	0.4	16	14	6	5	14	10	9	7
+	0.5	21	21	14	14	13	12	17	16
K	0.6	16	16	12	12	21	21	22	22
N	0.7	18	18	19	19	13	12	25	25
O_3	0.8	23	23	10	10	22	22	35	35
	>0.8	12	12	1	1	47	47	33	32

Month 4

		Replicate 1		Replicate 2		Replicate 3		Replicate 4	
	Size mg	No.	Germ.	No.	Germ.	No.	Germ.	No.	Germ.
C	To 0.3	11	0	7	0	2	2	8	2
O	0.4	9	6	6	1	3	2	10	9
N	0.5	20	18	13	8	14	14	18	18
T	0.6	23	23	39	36	9	8	23	23
R	0.7	38	38	29	25	14	14	29	29
O	0.8	28	28	31	31	12	12	6	6
L	>0.8	13	13	17	17	15	15	0	0
G	0.3	11	0	7	0	2	0	9	2
A	0.4	10	5	6	5	2	2	10	10
+	0.5	20	19	12	10	14	14	18	18
K	0.6	23	23	39	37	10	10	22	22
N	0.7	38	38	29	24	14	14	29	29
O_3	0.8	27	27	31	29	13	13	7	7
	>0.8	13	13	17	17	14	14	0	0

Month 5

		Replicate 1		Replicate 2		Replicate 3		Replicate 4	
	Size mg	No.	Germ.	No.	Germ.	No.	Germ.	No.	Germ.
C	To 0.3	8	2	4	4	5	0	11	5
O	0.4	9	6	13	8	5	3	9	6
N	0.5	25	25	18	18	12	9	16	13
T	0.6	22	22	13	13	14	10	22	22
R	0.7	21	21	20	20	26	24	25	25
O	0.8	18	18	24	24	30	29	28	28
L	>0.8	31	31	34	33	23	23	10	10
G	0.3	8	1	4	0	5	0	10	4
A	0.4	9	7	12	12	4	1	9	5
+	0.5	25	25	19	17	12	9	16	16
K	0.6	21	21	13	12	14	14	22	20
N	0.7	21	21	20	20	26	23	26	26
O_3	0.8	19	19	23	23	30	30	28	28
	>0.8	30	30	34	33	23	23	9	9

Month 6

		Replicate 1		Replicate 2		Replicate 3		Replicate 4	
	Size mg	No.	Germ.	No.	Germ.	No.	Germ.	No.	Germ.
C	To 0.3	5	0	9	0	5	0	10	2
O	0.4	8	5	5	2	8	5	12	11
N	0.5	14	7	13	12	13	12	25	24
T	0.6	23	21	15	15	20	20	15	15
R	0.7	32	26	40	39	31	31	19	19
O	0.8	22	17	22	22	26	26	16	16
L	>0.8	8	8	3	3	13	13	5	5
G	0.3	5	1	9	0	5	0	10	4
A	0.4	8	4	5	2	8	2	12	12
+	0.5	14	12	12	12	13	13	25	23
K	0.6	23	17	15	14	21	21	15	14
N	0.7	32	22	41	41	31	31	20	20
O_3	0.8	23	22	23	23	27	27	15	15
	>0.8	7	7	2	2	13	13	5	5

Month 7

	Size mg	Replicate 1		Replicate 2		Replicate 3		Replicate 4	
		No.	Germ.	No.	Germ.	No.	Germ.	No.	Germ.
C	To 0.3	2	0	5	0	4	0	1	0
O	0.4	4	0	11	2	7	5	5	3
N	0.5	9	7	15	7	6	6	10	4
T	0.6	14	14	23	13	5	5	17	10
R	0.7	26	26	19	15	16	16	23	20
O	0.8	37	37	15	9	18	18	9	7
L	>0.8	21	21	30	22	15	15	1	1
G	0.3	1	0	5	0	4	2	1	0
A	0.4	5	2	11	5	7	3	5	4
+	0.5	8	6	15	9	6	6	9	7
K	0.6	14	13	23	13	6	6	17	7
N	0.7	26	26	19	12	15	15	23	19
O_3	0.8	37	37	15	7	18	18	8	8
	>0.8	20	20	30	26	14	14	0	0

Month 8

	Size mg	Replicate 1		Replicate 2		Replicate 3		Replicate 4	
		No.	Germ.	No.	Germ.	No.	Germ.	No.	Germ.
C	To 0.3	3	0	1	0	6	0	6	0
O	0.4	6	1	10	8	8	4	6	2
N	0.5	4	4	19	17	23	23	13	10
T	0.6	8	6	21	21	27	27	17	17
R	0.7	9	9	28	28	21	21	27	27
O	0.8	13	13	28	27	12	12	25	25
L	>0.8	62	62	10	10	37	37	30	29
G	0.3	3	0	2	0	5	0	7	2
A	0.4	5	0	10	8	9	7	6	4
+	0.5	5	3	19	19	22	21	13	9
K	0.6	9	9	21	21	27	26	16	15
N	0.7	9	9	28	28	22	22	16	15
O_3	0.8	13	13	27	26	12	12	25	24
	>0.8	62	62	11	11	37	37	29	27

Month 10

	Size mg	Replicate 1		Replicate 2		Replicate 3		Replicate 4	
		No.	Germ.	No.	Germ.	No.	Germ.	No.	Germ.
C	To 0.3	1	0	5	0	3	0	5	0
O	0.4	4	3	5	2	9	5	5	3
N	0.5	14	10	9	6	16	14	13	12
T	0.6	14	10	17	17	31	21	17	17
R	0.7	25	18	23	23	23	18	28	28
O	0.8	28	21	21	20	16	11	25	25
L	>0.8	25	22	16	16	12	12	9	9
G	0.3	1	0	5	1	4	1	5	0
A	0.4	5	1	4	4	9	4	4	3
+	0.5	14	9	9	7	15	13	13	13
K	0.6	13	6	17	17	32	19	16	16
N	0.7	25	20	23	23	22	15	28	28
O_3	0.8	29	29	21	21	16	14	25	25
	>0.8	24	22	17	17	12	10	9	9

Month 12

		Replicate 1		Replicate 2		Replicate 3		Replicate 4	
	Size mg	No.	Germ.	No.	Germ.	No.	Germ.	No.	Germ.
C	To 0.3	8	5	5	0	5	1	13	1
O	0.4	20	20	6	2	6	3	20	8
N	0.5	14	14	10	7	9	5	18	10
T	0.6	9	8	14	14	10	10	19	14
R	0.7	15	15	17	16	13	13	22	18
O	0.8	19	19	19	19	24	23	3	3
L	>0.8	13	13	57	57	54	54	0	0
G	0.3	7	6	5	0	4	0	13	0
A	0.4	21	21	5	2	7	2	19	7
+	0.5	13	12	10	8	9	6	19	11
K	0.6	9	8	14	14	10	10	19	12
N	0.7	16	16	17	17	13	13	21	17
O_3	0.8	18	18	19	19	24	24	3	3
	>0.8	14	14	56	56	53	53	0	0

Appendix II b

Length of Embryos (mm) from Achenes of Known Weight (mg)

	wt mg	lth mm
1	0.258	1.89
2	0.428	2.95
3	0.438	2.34
4	0.501	3.79
5	0.545	2.32
6	0.560	3.55
7	0.568	2.71
8	0.579	2.66
9	0.610	3.16
10	0.633	3,32
11	0.665	3.16
12	0.667	3.16
13	0.676	2.68
14	0.678	2.53
15	0.726	2.82
16	0.744	2.79
17	0.756	3.16
18	0.756	3.16
19	0.762	3.03
20	0.765	2.89
21	0.793	3.37
22	0.805	3.11
23	0.844	2.71
24	0.849	3.00
25	0.885	3.42
26	0.892	3.26
27	0.918	3.42
28	0.924	3.84
29	0.925	3.37
30	0.956	3.37
31	0.962	3.32
32	0.966	2.97
33	1.002	3.13
34	1.009	3.68
35	1.043	3.42
36	1.137	3.26
37	1.190	3.16

Non-destructive Sampling of W3 and M2 (fresh weight in g).

14 days	21 days	28 days	35 days	42 days	49 days	56 days	63 days	70 days	77 days	clone	size
0.0143	0.0514	0.0903	0.1881	0.3409	0.6998	1.65	2.18	2.27	2.20	1	1
0.0117	0.0764	0.1544	0.4407	0.7749	1.5227	2.95	4.05	4.16	3.92	1	1
0.0098	0.0259	0.0369	0.0617	0.0837	0.1069	0.15	0.21	0.24	0.20	1	1
0.0133	0.0793	0.1552	0.3800	0.6448	1.1154	2.14	2.65	2.85	3.00	1	1
0.0257	0.0708	0.1488	0.4223	0.6766	1.2309	2.17	2.94	2.85	3.09	1	1
0.0199	0.0322	0.0327	0.0408	0.0876	0.1644	0.44	0.53	0.58	0.56	1	1
0.0100	0.0443	0.0558	0.1275	0.1822	0.2297	0.39	0.54	0.64	0.64	1	1
0.0320	0.1640	0.3785	0.8499	1.4337	2.7097	4.48	5.75	6.19	6.76	1	2
0.0572	0.1621	0.3856	1.0705	1.8278	3.5126	5.50	7.19	7.93	8.94	1	2
0.0251	0.0295	0.0765	0.0947	0.1715	0.3589	0.66	0.72	0.70	0.71	1	2
0.0297	0.0584	0.0861	0.2165	0.3855	0.7060	1.21	1.59	1.90	2.24	1	2
0.0328	0.1762	0.4157	1.1376	2.0091	3.8646	6.61	8.63	9.87	10.96	1	2
0.0291	0.0766	0.1333	0.2841	0.5029	0.8171	1.54	2.03	2.33	2.34	1	2
0.0971	0.2946	0.7186	1.7603	2.9667	4.8457	7.48	8.91	9.96	10.00	1	3
0.0670	0.2665	0.5988	1.4943	2.6823	5.0050	8.53	11.05	11.94	12.93	1	3
0.0272	0.1100	0.2630	0.7553	1.2797	2.2310	3.98	4.83	4.84	5.13	1	3
0.0376	0.1696	0.3971	0.9799	1.6747	3.1624	5.87	8.11	9.27	9.20	1	3
0.0410	0.0636	0.0361	0.0567	0.1089	0.1502	0.33	0.47	0.53	0.49	1	3
0.0424	0.0991	0.1474	0.2016	0.2240	0.3861	0.99	1.04	1.07	0.93	1	3
0.0237	0.1031	0.2893	0.8298	1.6037	3.3714	6.24	8.83	9.52	9.76	2	1
0.0039	0.0125	0.0303	0.1116	0.2469	0.5552	1.12	1.60	1.71	1.78	2	1
0.0405	0.1406	0.3110	0.8741	1.7195	3.7312	7.23	9.68	10.92	11.37	2	1
0.0207	0.0975	0.2487	0.6422	1.1853	2.3016	4.14	5.78	5.91	5.66	2	1
0.0166	0.1002	0.2803	0.8158	1.4633	2.8151	5.03	6.60	6.95	6.65	2	1
0.0180	0.0676	0.1819	0.4802	0.8787	1.5409	2.74	3.42	3.69	3.70	2	1
0.0334	0.1032	0.2671	0.7704	1.5082	2.9247	5.24	6.69	6.79	7.59	2	1
0.0366	0.1231	0.3245	0.8114	1.4356	2.4121	3.80	4.92	5.42	5.56	2	1
0.0118	0.0311	0.0805	0.2843	0.6404	1.5567	3.15	4.14	4.15	4.31	2	2
0.0248	0.1088	0.2822	0.8412	1.5969	3.1912	5.57	7.11	7.80	9.10	2	2
0.0228	0.0261	0.0355	0.0693	0.1033	0.1044	0.15	0.20	0.24	0.26	2	2
0.0231	0.0618	0.1692	0.5437	1.0038	1.9914	3.45	5.05	5.66	5.43	2	2
0.0686	0.1495	0.3441	0.9709	1.8610	3.7900	7.03	9.05	9.58	10.10	2	2
0.0407	0.1252	0.3379	0.9470	1.6501	3.1531	5.65	7.53	8.03	9.75	2	2
0.0419	0.0623	0.1658	0.4976	1.0124	2.1525	4.32	6.02	6.70	6.55	2	2
0.0264	0.0927	0.2223	0.5670	1.0502	2.0054	3.68	4.85	5.31	5.62	2	2
0.0302	0.0505	0.0960	0.2702	0.4430	0.9105	2.00	2.71	3.18	3.51	2	2
0.0423	0.1559	0.3986	1.2235	2.0422	3.8845	6.99	9.74	11.02	11.03	2	3
0.0544	0.1677	0.4160	1.1029	2.1054	4.1265	6.93	9.08	9.78	9.92	2	3
0.0539	0.0825	0.2168	0.6073	1.0333	1.9804	3.58	4.76	5.40	5.84	2	3
0.0795	0.2670	0.6921	1.9549	3.4735	6.8809	10.80	12.80	13.85	13.78	2	3
0.0214	0.0713	0.1321	0.3040	0.4733	0.8747	1.35	1.88	1.88	2.00	2	3
0.0573	0.0956	0.2383	0.4183	0.6530	1.2165	2.72	3.68	3.98	3.93	2	3
0.0399	0.2009	0.5180	1.2173	2.1134	3.8255	6.91	9.09	10.41	10.65	2	3
0.0684	0.1956	0.5339	1.4678	2.6068	4.9138	8.01	10.01	12.35	10.80	2	3

Note:

Figures under columns 14-77days are fresh weights of plants in grams.
Clone 1 refers to W3 and clone 2 to M2.
Size 1 represents achenes less than 0.5mg, size 2 for achenes between 0.6 and 0.7mg and size 3 for achenes greater than 0.7mg fresh weight.

Appendix IIIb

Summary of fresh weight (g) for root/shoot allocation.

Column a, root fresh weight; b, shoot fresh weight; c, root/shoot ratio; d, clone where 1 = W3 and 2 = M2; e, size where 1 = <0.5mg and 2 = >0.7mg; f, age of plant in days.

a	b	c	d	e	f
0.0137	0.0306	0.45	1	1	14
0.0058	0.0185	0.31	1	1	14
0.0160	0.0270	0.60	1	1	14
0.0084	0.0149	0.56	1	1	14
0.0236	0.0907	0.26	1	1	21
0.0560	0.1658	0.34	1	1	21
0.0240	0.0838	0.29	1	1	21
0.0481	0.1301	0.37	1	1	21
0.0324	0.0569	0.57	1	1	28
0.0578	0.0975	0.59	1	1	28
0.0975	0.2414	0.40	1	1	28
0.1031	0.1812	0.57	1	1	28
0.2046	0.2363	0.87	1	1	35
0.6863	0.8016	0.86	1	1	35
0.2314	0.3828	0.61	1	1	35
0.0506	0.0876	0.58	1	1	35
0.9125	1.0127	0.90	1	1	42
0.4210	0.6856	0.61	1	1	42
1.0485	1.4275	0.73	1	1	42
0.2703	0.3579	0.76	1	1	42
0.9306	1.0771	0.86	1	1	49
0.1919	0.2106	0.91	1	1	49
0.2367	0.3245	0.78	1	1	49
0.5594	0.3891	0.92	1	1	49
0.1700	0.2900	0.59	1	1	56
0.3400	0.9500	0.36	1	1	56
2.0900	2.4400	0.86	1	1	56
2.6500	3.4900	0.76	1	1	56
1.1700	1.5500	0.75	1	1	63
0.7300	0.9800	0.74	1	1	63
3.3000	3.1800	1.04	1	1	63
3.6000	4.3800	0.82	1	1	63
7.5300	6.1300	1.23	1	1	70
1.2100	0.8600	1.41	1	1	70
6.0900	6.3500	0.96	1	1	70
0.0241	0.0496	0.49	1	2	14
0.0281	0.0485	0.58	1	2	14
0.0145	0.0285	0.51	1	2	14
0.0275	0.0549	0.50	1	2	14
0.0218	0.0514	0.42	1	2	21
0.0830	0.2239	0.37	1	2	21
0.0773	0.2083	0.37	1	2	21
0.0827	0.1743	0.47	1	2	21
0.1487	0.2732	0.54	1	2	28
0.1024	0.2601	0.39	1	2	28
0.1579	0.3092	0.51	1	2	28
0.1758	0.2977	0.59	1	2	28
0.1441	0.3659	0.39	1	2	35
0.0284	0.4490	0.63	1	2	35
0.9233	1.2892	0.72	1	2	35
0.8918	1.3058	0.68	1	2	35
0.1219	0.2957	0.41	1	2	42
0.6694	1.0616	0.63	1	2	42
0.7637	1.2350	0.52	1	2	42
0.4766	0.6799	0.69	1	2	42
2.1026	2.2282	0.94	1	2	49
0.5653	0.6692	0.84	1	2	49
2.2214	3.0601	0.73	1	2	49
1.0693	1.4834	0.72	1	2	49
0.9100	1.1100	0.82	1	2	56
1.6000	1.5300	1.05	1	2	56
3.8600	4.0700	0.95	1	2	56
2.8700	3.0400	0.95	1	2	56
9.7700	8.6700	1.13	1	2	63
4.7600	4.6000	1.03	1	2	63
3.0400	2.9100	1.04	1	2	63
4.9000	4.9000	1.02	1	2	63
9.3200	7.6400	1.22	1	2	70
11.6200	11.5900	1.00	1	2	70
8.5400	7.7500	1.10	1	2	70
10.8100	10.1000	1.07	1	2	70
1.7100	1.3000	1.32	1	2	77
5.2300	4.9900	1.05	1	2	77
10.1500	8.7900	1.16	1	2	77
4.0400	4.0300	1.00	1	2	77

a	b	c	d	e	f
0.0022	0.0053	0.42	2	1	14
0.0027	0.0065	0.42	2	1	14
0.0055	0.0108	0.51	2	1	14
0.0059	0.0105	0.56	2	1	14
0.0040	0.0167	0.24	2	1	21
0.0183	0.0731	0.25	2	1	21
0.0377	0.1069	0.35	2	1	21
0.0094	0.0273	0.34	2	1	21
0.0535	0.1129	0.47	2	1	28
0.0840	0.1393	0.60	2	1	28
0.2325	0.3901	0.60	2	1	28
0.0164	0.1088	0.15	2	1	28
0.0283	0.0405	0.70	2	1	35
0.1568	0.2130	0.74	2	1	35
0.1122	0.1514	0.74	2	1	35
0.3946	0.5111	0.77	2	1	35
0.7587	1.0387	0.57	2	1	42
0.7020	1.0367	0.68	2	1	42
0.0504	0.0733	0.69	2	1	42
0.9861	1.2185	0.81	2	1	42
0.6124	0.5939	1.03	2	1	49
0.0170	0.0400	0.42	2	1	49
0.1369	0.1839	0.74	2	1	49
0.7435	0.8579	0.87	2	1	49
0.7700	1.1000	0.70	2	1	56
1.8500	2.5900	0.71	2	1	56
0.1300	0.2400	0.54	2	1	56
2.2300	2.5800	0.86	2	1	56
0.2400	0.3100	0.77	2	1	63
2.3100	2.3000	1.00	2	1	63
1.4600	1.2100	1.21	2	1	63
1.9600	3.6100	0.54	2	1	63
1.1600	1.7800	0.65	2	1	70
6.5100	6.5100	1.00	2	1	70
7.6800	7.5400	1.02	2	1	70
1.3600	1.0900	1.25	2	1	70
2.4700	3.1700	0.78	2	1	77
4.2900	4.0400	1.06	2	1	77
4.6000	4.2700	1.08	2	1	77
4.6700	4.0800	1.14	2	1	77
0.0340	0.0488	0.70	2	2	14
0.0309	0.0436	0.71	2	2	14
0.0372	0.0662	0.56	2	2	14
0.0348	0.0554	0.63	2	2	14
0.0142	0.0277	0.51	2	2	21
0.0585	0.1633	0.36	2	2	21
0.1152	0.2845	0.41	2	2	21
0.0346	0.0735	0.47	2	2	21
0.0371	0.1200	0.31	2	2	28
0.1565	0.3265	0.48	2	2	28
0.3758	0.4576	0.82	2	2	28
0.0313	0.0771	0.41	2	2	28
1.2325	1.6361	0.75	2	2	35
0.5848	1.0525	0.56	2	2	35
0.1479	0.0272	0.54	2	2	35
0.9046	1.3654	0.66	2	2	35
1.8566	2.1595	0.86	2	2	42
2.3053	2.9955	0.79	2	2	42
0.8443	1.4131	0.60	2	2	42
0.6305	0.9637	0.65	2	2	42
0.6486	0.6546	0.99	2	2	49
0.3775	0.4259	0.87	2	2	49
0.8039	0.9952	0.81	2	2	49
0.2098	0.2771	0.76	2	2	49
1.8400	2.1500	0.86	2	2	56
1.2300	1.7900	0.69	2	2	56
1.5700	2.0700	0.72	2	2	56
1.6100	1.7300	0.93	2	2	56
7.1100	9.1900	0.77	2	2	63
1.1400	1.0900	1.05	2	2	63
3.7900	3.6900	1.03	2	2	63
4.4300	4.3800	1.01	2	2	63
9.2700	6.7600	1.37	2	2	70
15.3600	14.6600	1.05	2	2	70
4.8800	4.7600	1.03	2	2	70
12.3800	14.8600	0.83	2	2	70
4.9800	3.3000	1.51	2	2	77
14.9100	16.2400	0.92	2	2	77
10.0400	6.3200	1.59	2	2	77
16.4100	13.8500	1.18	2	2	77

Appendix III c   Leaf Turnover Data for W2/63

Column a is cohort number; b, number of leaves in cohort; c, age in days of birth of cohort; d, age in days of onset of death of cohort; e, age in days of complete death of cohort; f, duration of cohort in days.

a	b	c	d	e	f
1	2	23	56	98	75
2	2	28	63	98	70
3	2	35	70	98	63
4	3	41	72	98	57
5	2	44	82	98	54
6	2	47	103	119	72
7	3	50	103	119	69
8	8	55	82	98	43
9	3	57	114	121	64
10	8	61	98	112	51
11	6	63	98	119	56
12	4	65	119	128	63
13	5	68	119	128	60
14	4	70	124	138	68
15	4	72	119	140	68
16	9	76	126	158	82
17	12	82	128	146	64
18	5	84	119	158	74
19	9	89	117	173	84
20	7	92	126	151	59
21	11	98	134	165	67
22	4	100	141	158	58
23	8	103	138	152	49
24	5	105	144	165	60
25	4	107	134	148	41
26	6	112	146	158	46
27	6	114	148	162	48
28	6	117	165	172	55
29	6	119	165	173	54
30	8	124	160	173	49
31	8	126	165	193	67
32	7	128	144	193	65
33	10	132	165	173	41
34	16	134	173	193	59
35	22	138	173	197	59
36	9	141	173	207	66
37	7	144	179	189	45
38	9	146	179	195	49
39	7	148	179	193	45
40	3	151	173	186	35
41	1	153	186	186	33
42	3	155	193	207	52
43	9	158	207	225	67
44	15	160	193	211	51
45	13	162	193	209	47
46	16	165	207	214	49
47	11	167	207	218	51
48	6	169	207	214	45
49	5	172	207	230	58
50	4	174	207	227	53
51	5	176	214	256	80
52	7	179	207	223	44
53	5	181	207	230	49
54	5	183	214	230	47
55	16	186	214	235	49
56	8	189	214	230	41
57	6	193	214	263	70
58	3	195	221	249	54
59	11	197	230	278	81
60	38	207	214	284	77
61	7	209	242	256	47
62	2	211	249	278	67
63	5	214	221	242	28
64	4	216	256	270	54
65	2	218	249	298	80
66	6	221	249	286	65
67	5	223	278	293	70
68	3	225	256	297	72
69	9	230	349	397	167
70	1	232	249	249	17
71	1	235	356	356	121
72	1	237	293	293	56
73	4	239	278	321	82
74	11	242	278	370	128
75	3	244	284	356	112
76	3	246	256	321	75
77	7	249	293	330	81
78	3	251	298	300	49
79	4	253	278	330	77
80	4	256	278	330	74
81	2	258	293	335	77
82	4	260	300	337	77
83	7	263	314	356	93
84	4	265	293	363	98
85	3	267	356	363	96

a	b	c	d	e	f
86	10	270	335	384	114
87	2	272	293	356	84
88	2	277	335	363	86
89	2	279	321	339	60
90	3	281	356	356	75
91	4	284	356	363	79
92	2	286	356	356	70
93	6	293	356	363	70
94	6	297	356	365	68
95	4	300	356	370	70
96	3	302	363	370	68
97	4	304	335	384	80
98	5	307	356	391	84
99	5	309	356	370	61
100	2	311	363	363	52
101	2	314	377	377	63
102	3	316	356	391	75
103	5	318	370	422	104
104	3	321	356	422	101
105	0	0	0	0	0
106	4	325	384	391	66
107	2	330	377	384	54
108	0	0	0	0	0
109	2	335	370	384	49
110	0	0	0	0	0
111	7	339	370	468	129
112	23	356	370	447	91
113	8	358	384	462	104
114	10	360	391	468	108
115	7	363	384	468	105
116	5	365	391	477	112
117	8	367	391	447	80
118	7	370	398	477	107
119	3	372	398	477	105
120	4	374	391	447	73
121	5	377	422	477	100
122	3	379	412	440	61
123	2	381	447	468	87
124	4	384	447	468	84
125	3	386	422	468	82
126	1	388	462	462	74
127	2	391	412	447	56
128	2	393	447	447	54
129	2	395	412	426	31
130	2	398	477	483	85
131	3	400	412	447	47
132	2	402	447	456	54
133	2	405	468	477	72
134	2	409	468	468	59
135	5	412	456	504	92
136	7	422	447	517	95
137	4	426	483	525	99
138	6	428	468	519	91
139	5	430	456	504	74
140	7	433	477	477	44
141	6	437	468	539	102
142	7	440	468	525	85
143	6	442	477	539	97
144	4	444	477	532	88
145	4	447	477	539	92
146	12	456	468	511	55
147	5	458	477	483	25
145	10	462	483	498	36
149	5	464	489	511	47
150	6	468	483	498	30
151	2	471	489	498	27
152	6	477	519	532	55
153	12	479	498	545	66
154	9	483	511	532	49
155	5	486	498	511	25
156	10	489	525	539	50
157	13	493	525	554	61
158	12	498	532	545	47
159	5	500	532	545	45
160	8	504	545	545	41
161	4	507	545	545	38
162	7	511	532	560	49
163	7	514	545	554	40
164	12	517	539	554	37
165	11	521	545	554	33

Leaf Turnover Data for W2/81

a	b	c	d	e	f
1	2	23	57	98	75
2	2	28	57	98	70
3	2	35	63	98	63
4	5	41	70	98	57
5	3	44	76	98	54
6	2	47	98	119	72
7	2	50	103	117	67
8	5	55	119	128	73
9	1	57	103	103	46
10	6	61	119	144	83
11	3	63	117	151	88
12	4	65	126	141	76
13	3	68	119	155	87
14	3	70	128	160	90
15	3	72	132	162	90
16	7	76	126	146	70
17	7	82	128	148	66
18	2	84	138	160	76
19	3	89	144	160	71
20	1	92	134	134	42
21	4	98	128	158	60
22	2	100	144	165	65
23	3	103	134	160	57
24	5	105	146	162	57
25	2	107	138	162	55
26	6	112	153	165	53
27	3	114	146	167	53
28	3	117	141	167	50
29	3	119	141	158	39
30	7	124	160	173	49
31	4	126	155	165	39
32	4	128	165	173	45
33	6	132	151	165	33
34	3	134	165	173	39
35	4	138	148	165	27
36	4	141	165	173	32
37	4	144	165	173	29
38	5	146	173	193	47
39	3	148	176	193	45
40	6	151	179	189	38
41	4	153	179	186	33
42	8	155	179	193	38
43	6	158	173	186	28
44	3	160	193	207	47
45	4	162	193	209	47
46	4	165	193	211	46
47	10	167	179	207	40
48	4	169	193	207	38
49	6	172	193	218	46
50	4	174	207	225	51
51	2	176	207	242	66
52	4	179	207	207	28
53	3	181	207	225	44
54	7	183	207	221	38
55	3	186	214	237	51
56	8	189	207	221	32
57	8	193	216	230	37
58	4	195	221	221	26
59	6	197	221	230	33
60	19	207	221	235	28
61	10	209	221	239	30
62	2	211	235	235	24
63	6	214	235	242	28
64	9	216	230	242	26
65	3	218	242	242	24
66	3	221	242	249	28
67	7	223	249	249	26
68	8	225	249	256	31
69	11	230	242	263	33
70	5	232	256	256	24
71	3	235	265	330	95
72	6	237	252	263	26
73	5	239	263	272	33
74	6	242	263	339	97
75	9	244	270	339	95
76	3	246	270	270	24
77	10	249	307	330	81
78	7	251	307	339	88
79	7	253	307	356	103
80	5	256	330	335	79
81	6	258	330	356	98
82	7	260	330	339	79
83	6	263	330	339	76
84	4	265	335	356	91
85	7	267	330	356	89
86	4	270	330	339	69
87	6	272	339	356	84
88	13	277	330	356	79
89	4	279	304	339	60
90	1	281	339	339	58
92	2	286	339	358	72
92	2	286	339	358	72
93	7	293	330	356	63
94	4	297	356	365	68
95	2	300	330	356	56
96	4	302	356	370	68
97	6	304	356	377	73
98	6	307	356	422	115
99	4	309	356	381	72
100	3	311	356	356	45
101	6	314	356	356	42
102	7	316	356	376	60
103	6	318	356	412	94
104	2	321	356	363	42
105	7	323	356	400	77
106	1	325	377	377	52
107	4	330	356	386	56
108	4	332	356	370	38
109	3	335	356	384	49
110	6	337	370	422	85
111	7	339	377	422	83
112	49	356	372	426	70
113	12	358	384	409	51
114	11	360	391	433	73
115	11	363	391	422	59
116	1	365	426	426	61
117	4	367	398	412	45
118	7	370	384	422	52
119	4	372	412	426	54
120	8	374	412	426	52
121	5	377	412	440	63
122	1	379	422	422	43
123	0	0	0	0	0
124	1	384	422	422	38
125	3	386	426	426	40
126	0	0	0	0	0
127	2	391	422	426	35
128	3	393	422	468	75
129	4	395	422	477	82
130	10	398	422	477	79
131	6	400	422	433	33
132	7	402	426	489	87
133	3	405	433	462	57
134	5	409	433	498	89
135	3	412	433	498	86
136	11	422	440	486	64
137	7	426	447	447	21
138	4	428	440	456	28
139	5	430	456	456	26
140	3	433	456	498	65
141	9	437	456	498	61
142	4	440	462	468	28
143	4	442	462	468	26
144	2	444	468	468	24
145	5	447	468	477	30
146	12	456	477	498	42
147	3	458	477	493	35
148	9	462	477	489	27
149	4	464	483	483	19
150	5	468	483	489	21
151	5	471	498	511	40
152	7	477	498	514	37
153	3	479	493	511	32
154	10	483	498	514	31
155	5	486	498	504	18
156	5	489	504	511	22
157	12	493	511	525	32
158	6	498	525	532	34
159	6	500	525	545	45
160	5	504	511	525	21
161	3	507	525	532	25
162	8	511	525	539	28
163	8	514	525	532	18
164	8	517	532	539	22
165	9	521	539	545	24

Leaf Turnover Data for M5/75

a	b	c	d	e	f
1	2	23	57	57	34
2	2	28	65	98	70
3	2	35	70	91	56
4	3	41	76	97	56
5	3	44	76	100	56
6	2	47	98	119	72
7	6	50	98	119	69
8	5	55	98	112	57
9	2	57	119	126	69
10	4	61	124	130	69
11	4	63	121	128	65
12	3	65	117	122	57
13	5	68	128	140	72
14	2	70	134	134	64
15	3	72	132	139	67
16	3	76	132	139	63
17	7	82	134	148	66
18	2	84	138	144	60
19	3	89	141	148	59
20	2	92	141	141	49
21	6	98	146	152	54
22	1	100	146	146	46
23	6	103	141	148	45
24	2	105	138	145	40
25	1	107	141	141	34
26	3	112	151	158	46
27	1	114	155	155	41
28	4	117	151	158	41
29	1	119	153	158	39
30	4	124	151	158	34
31	4	126	148	158	32
32	3	128	151	158	30
33	6	132	158	165	33
34	3	134	165	165	31
35	5	138	165	165	27
36	5	141	165	173	32
37	4	144	173	179	35
38	4	146	179	186	40
39	1	148	179	179	31
40	3	151	179	207	56
41	1	153	179	179	26
42	4	155	179	195	40
43	5	158	186	186	28
44	4	160	193	193	33
45	2	162	193	193	31
46	2	165	193	193	28
47	1	167	193	193	26
48	4	169	193	207	38
49	5	172	207	207	35
50	3	174	193	209	35
51	2	176	207	207	31
52	4	179	207	218	39
53	0	0	0	0	0
54	4	183	207	214	31
55	4	186	214	225	39
56	1	189	214	214	25
57	6	193	214	225	32
58	2	195	221	225	30
59	4	197	221	228	31
60	12	207	221	235	28
61	3	209	235	242	33
62	2	211	242	249	38
63	4	214	242	249	35
64	1	216	249	249	33
65	2	218	249	256	38
66	4	221	249	249	28
67	3	223	249	249	26
68	1	225	256	256	31
69	5	230	256	265	35
70	4	232	256	256	24
71	1	235	260	260	25
72	4	237	263	263	26
73	3	239	263	270	31
74	4	242	263	277	35
75	3	244	270	278	34
76	2	246	293	307	61
77	5	249	300	321	72
78	5	251	307	330	79
79	0	0	0	0	0
80	3	256	293	307	51
81	3	258	300	356	98
82	4	260	300	356	96
83	2	263	307	307	44
84	4	265	300	356	91
85	3	267	307	330	63
86	5	270	314	330	60
87	0	0	0	0	0
88	4	277	335	356	79
89	2	279	321	335	56
90	1	281	321	321	40
91	0	0	0	0	0
92	3	286	356	363	77
93	1	293	339	339	46
94	2	297	358	363	66
95	0	0	0	0	0
96	0	0	0	0	0
97	4	304	339	358	54
98	0	0	0	0	0
99	4	309	356	363	54
100	4	311	356	405	94
101	3	314	356	363	49
102	11	316	356	400	84
103	7	318	363	422	104
104	11	321	356	370	49
105	3	323	370	377	54
106	0	0	0	0	0
107	4	330	377	391	61
108	6	332	377	388	56
109	3	335	377	384	49
110	5	337	356	384	47
111	2	339	377	377	38
112	15	356	377	405	49
113	5	358	391	405	47
114	2	360	402	433	73
115	6	363	398	422	59
116	6	365	405	422	57
117	1	367	398	398	31
118	3	370	422	447	77
119	8	372	405	426	54
120	1	374	456	456	82
121	3	377	422	426	49
122	2	379	422	422	43
123	0	0	0	0	0
124	1	384	426	426	42
125	0	0	0	0	0
126	0	0	0	0	0
127	2	391	422	447	56
128	0	0	0	0	0
129	1	395	422	422	27
130	0	0	0	0	0
131	2	400	426	433	33
132	1	402	426	426	24
133	3	405	447	498	93
134	3	409	433	456	47
135	2	412	447	458	46
136	13	422	440	489	67
137	4	426	447	498	72
138	3	428	447	456	28
139	2	430	456	468	38
140	6	433	463	479	46
141	4	437	483	500	63
142	3	440	462	480	40
143	1	442	462	462	20
144	4	444	477	489	45
145	3	447	477	489	42
146	9	456	477	498	42
147	4	458	489	498	40
148	3	462	483	498	36
149	3	464	489	489	25
150	4	468	489	498	30
151	2	471	498	498	27
152	4	477	498	511	34
153	5	479	504	511	32
154	1	483	504	504	21
155	6	486	504	519	33
156	5	489	511	511	22
157	4	493	519	525	32
158	7	498	519	525	27
159	4	500	525	525	25
160	4	504	525	525	21
161	3	507	525	532	25
162	6	511	525	532	21
163	6	514	532	539	25
164	6	517	539	539	22
165	5	521	539	545	24

Leaf Turnover Data for M5/97

a	b	c	d	e	f
1	2	23	56	98	75
2	2	28	65	98	70
3	2	35	70	98	63
4	4	41	72	98	57
5	3	44	76	98	54
6	2	47	89	119	72
7	3	50	119	128	78
8	5	55	103	119	64
9	1	57	128	128	71
10	2	61	117	126	65
11	3	63	119	132	69
12	2	65	117	144	79
13	4	68	119	124	56
14	2	70	124	138	68
15	3	72	119	146	74
16	3	76	141	158	82
17	4	82	124	144	62
18	1	84	126	126	42
19	2	89	165	176	87
20	2	92	146	158	66
21	4	98	146	151	53
22	2	100	148	163	63
23	4	103	148	160	57
24	1	105	165	165	60
25	2	107	138	158	51
26	3	112	141	151	39
27	2	114	141	153	39
28	2	117	148	162	45
29	1	119	158	158	39
30	7	124	137	158	34
31	2	126	136	158	32
32	3	128	138	158	30
33	5	132	158	165	33
34	2	134	165	172	38
35	6	138	158	165	27
36	4	141	165	173	32
37	5	144	165	176	32
38	3	146	173	179	33
39	3	148	173	181	33
40	5	151	173	179	28
41	5	153	179	186	33
42	3	155	186	186	31
43	4	158	186	193	35
44	3	160	186	193	33
45	3	162	193	193	31
46	2	165	193	193	28
47	1	167	193	193	26
48	2	169	186	193	24
49	4	172	193	209	37
50	3	174	207	207	33
51	2	176	207	207	31
52	3	179	207	207	28
53	1	181	249	249	68
54	4	183	207	207	24
55	3	186	214	214	28
56	4	189	214	221	32
57	6	193	221	230	37
58	2	195	221	230	35
59	2	197	221	230	33
60	15	207	221	235	28
61	3	209	235	235	26
62	3	211	235	242	31
63	3	214	242	242	28
67	2	216	242	242	26
65	3	218	242	249	31
66	1	221	249	249	28
67	4	223	249	249	26
68	1	225	249	249	24
69	4	230	249	278	48
70	5	232	249	256	24
71	1	235	256	256	21
72	5	237	256	263	26
73	2	239	263	263	24
74	2	242	263	270	28
75	5	244	270	293	49
76	2	246	284	370	124
77	4	249	300	321	72
78	0	0	0	0	0
79	5	253	307	335	82
80	3	256	300	330	74
81	3	258	284	321	63
82	1	260	293	293	33
83	5	263	330	363	100
84	5	265	330	370	105
85	4	267	321	377	110

a	b	c	d	e	f
86	2	270	363	370	100
87	0	0	0	0	0
88	5	277	356	377	100
89	2	279	363	377	98
90	1	281	307	307	26
91	3	284	356	377	93
92	3	286	339	370	84
93	3	293	377	377	84
94	4	297	363	377	80
95	4	300	377	384	84
96	4	302	356	384	82
97	1	304	363	363	59
98	3	307	377	377	70
99	3	309	370	379	70
100	1	311	384	384	73
101	9	314	370	377	63
102	2	316	377	377	61
103	4	318	363	377	59
104	3	321	377	377	56
105	0	0	0	0	0
106	2	325	377	377	52
107	3	330	377	377	47
108	8	332	370	384	52
109	4	335	384	384	49
110	6	337	377	384	47
111	2	339	384	384	45
112	10	356	384	390	34
113	3	358	390	398	40
114	4	360	398	440	80
115	7	363	391	422	59
116	7	365	398	422	57
117	4	367	398	405	38
118	6	370	405	412	42
119	5	372	422	447	75
120	7	374	440	447	73
121	5	377	422	447	70
122	10	379	422	456	77
123	4	381	440	447	66
124	6	384	440	468	84
125	2	386	422	447	61
126	0	0	0	0	0
127	1	391	447	447	56
128	2	393	440	447	54
129	2	395	447	458	63
130	2	398	440	483	85
131	0	0	0	0	0
132	2	402	440	440	38
133	1	405	456	456	51
134	0	0	0	0	0
135	0	0	0	0	0
136	1	422	447	447	25
137	7	426	447	511	85
138	2	428	456	456	28
139	3	430	447	468	38
140	3	433	462	477	44
141	5	437	468	477	40
142	2	440	468	489	49
143	4	442	468	477	35
144	1	444	477	477	33
145	4	447	477	532	85
146	8	456	477	489	33
147	2	458	489	489	31
148	5	462	483	504	42
149	3	464	483	498	34
150	3	468	498	504	36
151	3	471	489	498	27
152	10	477	489	504	27
153	2	479	504	511	32
154	6	483	504	511	28
155	5	486	511	525	39
156	6	489	511	525	36
157	6	493	511	519	26
158	7	498	525	525	27
159	4	500	525	532	32
160	6	504	525	532	28
161	5	507	525	532	25
162	8	511	532	539	28
163	7	514	532	539	25
164	2	517	539	539	22
165	9	521	539	545	24

Leaf Turnover Data for M5/105

a	b	c	d	e	f
1	3	23	54	98	75
2	2	28	54	98	70
3	2	35	70	98	63
4	4	41	65	98	57
5	3	44	72	98	54
6	2	47	82	119	72
7	3	50	98	119	69
8	3	55	98	103	48
9	3	57	119	126	69
10	2	61	124	131	70
11	3	63	132	146	83
12	3	65	119	143	78
13	4	68	128	135	67
14	2	70	132	146	76
15	2	72	134	144	72
16	3	76	141	149	73
17	3	82	138	145	63
18	2	84	138	143	59
19	3	89	146	153	64
20	2	92	138	142	50
21	4	98	141	147	49
22	0	0	0	0	0
23	3	103	146	153	50
24	2	105	144	158	53
25	2	107	155	162	55
26	3	112	153	160	48
27	3	114	153	160	46
28	3	117	160	167	50
29	1	119	158	158	39
30	5	124	165	165	41
31	3	126	144	158	32
32	2	128	155	165	37
33	5	132	146	160	28
34	3	134	151	158	24
35	6	138	165	173	35
36	4	141	165	173	32
37	5	144	173	180	36
38	2	146	179	186	40
39	1	148	179	179	31
40	5	151	179	186	35
41	4	153	165	186	33
42	5	155	186	193	38
43	5	158	186	193	35
44	2	160	193	200	40
45	2	162	193	193	31
46	2	165	193	207	42
47	3	167	193	207	40
48	1	169	214	214	45
49	1	172	207	207	35
50	0	0	0	0	0
51	4	176	207	214	38
52	3	179	207	214	35
53	3	181	207	214	33
54	2	183	207	214	31
55	3	186	214	221	35
56	3	189	214	221	32
57	5	193	221	230	37
58	1	195	221	221	26
59	4	197	221	230	33
60	10	207	230	235	28
61	3	209	235	235	26
62	0	0	0	0	0
63	3	214	242	249	35
64	2	216	242	242	26
65	3	218	242	242	24
66	2	221	249	249	28
67	3	223	249	249	26
68	3	225	256	263	38
69	2	230	256	256	26
70	1	232	263	263	31
71	2	235	263	263	28
72	2	237	263	263	26
73	1	239	270	270	31
74	2	242	284	339	97
75	1	244	284	284	40
76	2	246	293	293	47
77	3	249	293	293	44
78	2	251	293	293	42
79	2	253	307	307	54
80	3	256	293	307	51
81	0	0	0	0	0
82	2	260	293	330	70
83	3	263	300	321	58
84	0	0	0	0	0
85	2	267	330	335	68

a	b	c	d	e	f
86	1	270	330	330	60
87	2	272	330	335	63
88	1	277	330	330	53
89	2	279	330	335	56
90	1	281	330	330	49
91	0	0	0	0	0
92	1	286	339	339	53
93	1	293	335	335	42
94	2	297	330	335	38
95	2	300	356	356	56
96	2	302	356	360	58
97	0	0	0	0	0
98	1	307	356	356	49
99	0	0	0	0	0
100	1	311	356	356	45
101	5	314	339	356	42
102	2	316	356	356	40
103	2	318	335	356	38
104	3	321	356	363	42
105	2	323	363	363	40
106	2	325	370	370	45
107	3	330	370	377	47
108	1	332	384	384	52
109	2	335	384	404	69
110	1	337	391	391	54
111	1	339	422	422	83
112	5	356	405	426	70
113	1	358	422	422	64
114	2	360	422	429	69
115	1	363	422	422	59
116	0	0	0	0	0
117	0	0	0	0	0
118	1	370	422	422	52
119	3	372	412	426	54
120	1	374	422	422	48
121	1	377	425	425	48
122	0	0	0	0	0
123	1	381	428	428	47
124	2	384	412	422	38
125	0	0	0	0	0
126	0	0	0	0	0
127	0	0	0	0	0
128	1	393	422	422	29
129	1	395	426	426	31
130	3	398	426	433	35
131	0	0	0	0	0
12	3	402	426	440	38
133	0	0	0	0	0
134	2	409	423	435	26
135	1	412	423	423	11
136	10	422	440	483	61
137	2	426	456	468	42
138	3	428	462	477	49
139	2	430	483	483	53
140	3	433	477	494	61
141	3	437	483	489	52
142	3	440	483	489	49
143	0	0	0	0	0
144	4	444	483	489	45
145	2	447	489	511	64
146	5	456	489	498	42
147	2	456	483	489	33
148	5	462	489	504	42
149	2	464	483	498	34
150	2	468	498	504	36
151	2	471	504	504	33
152	5	477	504	511	34
153	2	479	504	510	31
154	5	483	511	525	42
155	1	486	525	525	39
156	6	489	519	525	36
157	3	493	525	525	32
158	6	498	525	534	36
159	3	500	525	525	25
160	4	504	525	539	35
161	2	507	532	532	25
162	5	511	532	532	21
163	7	514	532	539	25
164	4	517	539	546	29
165	6	521	539	546	25

Leaf Turnover Data for S1/62

a	b	c	d	e	f
1	2	23	57	98	75
2	2	28	70	98	70
3	2	35	72	98	63
4	2	41	76	98	57
5	2	44	76	98	54
6	1	47	119	119	72
7	2	50	105	119	69
8	5	55	105	137	82
9	2	57	105	138	81
10	4	61	105	119	58
11	3	63	119	145	82
12	2	65	126	140	75
13	5	68	137	145	77
14	2	70	138	148	78
15	2	72	138	148	76
16	6	76	138	153	77
17	7	82	138	155	73
18	5	84	140	158	74
19	4	89	145	165	76
20	3	92	142	160	68
21	5	98	145	160	62
22	3	100	138	148	48
23	4	103	145	160	57
24	2	105	158	158	53
25	2	107	148	155	48
26	2	112	158	158	46
27	5	114	158	158	44
28	2	117	158	158	41
29	1	119	158	158	39
30	5	124	165	165	41
31	5	126	165	165	39
32	4	128	165	165	37
33	5	132	158	158	26
34	6	134	165	165	31
35	6	138	173	173	35
36	2	141	165	165	24
37	5	144	165	173	29
38	2	146	173	173	27
39	5	148	173	173	25
40	5	151	172	179	28
41	5	153	173	183	30
42	6	155	207	214	59
43	7	158	207	218	60
44	3	160	207	207	47
45	2	162	207	214	52
46	3	165	207	214	49
47	1	167	207	207	40
48	2	169	207	207	38
49	5	172	207	214	42
50	4	174	207	225	51
51	1	176	263	263	87
52	4	179	214	225	46
53	3	181	214	230	49
54	4	183	225	230	47
55	6	186	214	230	44
56	4	189	221	230	41
57	10	193	221	263	70
58	2	195	230	235	40
59	2	197	230	235	38
60	16	207	230	249	42
61	10	209	235	270	61
62	2	211	242	256	45
63	7	214	249	256	42
64	6	216	249	278	62
65	3	218	249	249	31
66	4	221	249	249	28
67	6	223	249	256	33
68	8	225	249	263	38
69	9	230	256	270	40
70	7	232	249	263	31
71	7	235	263	263	28
72	6	237	263	270	33
73	5	239	263	278	39
74	7	242	263	276	34
75	7	244	263	278	34
76	3	246	270	270	24
77	10	249	270	300	51
78	15	251	270	330	79
79	9	253	284	335	82
80	11	256	278	335	79
81	11	258	307	356	98
82	7	260	335	363	103
83	6	263	300	356	93
84	10	265	278	356	91
85	9	267	335	356	89
86	13	270	321	363	93
87	11	272	339	356	84
88	10	277	330	356	79
89	2	279	356	363	84
90	0	0	0	0	0
91	3	284	339	356	72
92	0	0	0	0	0
93	4	293	339	339	46
94	2	297	339	356	59
95	3	300	356	356	56
96	5	302	339	391	89
97	1	304	363	363	59
98	0	0	0	0	0
99	0	0	0	0	0
100	0	0	0	0	0
101	3	314	335	356	42
102	0	0	0	0	0
103	0	0	0	0	0
104	1	321	356	356	35
105	0	0	0	0	0
106	0	0	0	0	0
107	3	330	363	379	49
108	0	0	0	0	0
109	2	335	384	384	49
110	4	337	384	412	75
111	4	339	363	405	66
112	19	356	363	412	56
113	7	358	405	429	71
114	4	360	405	468	108
115	5	363	391	412	49
116	2	365	391	422	57
117	5	367	391	422	55
118	2	370	405	412	42
119	1	372	412	412	40
120	1	374	440	440	66
121	0	0	0	0	0
122	0	0	0	0	0
123	2	381	405	405	24
124	2	384	412	412	28
125	2	386	412	422	36
126	0	0	0	0	0
127	0	0	0	0	0
128	0	0	0	0	0
129	2	395	422	477	82
130	1	398	477	477	79
131	1	400	422	422	22
132	1	402	426	426	24
133	0	0	0	0	0
134	4	409	426	468	59
135	1	412	440	440	28
136	7	422	456	468	46
137	5	426	447	477	51
138	1	428	447	447	19
139	1	430	489	489	59
140	0	0	0	0	0
141	5	437	477	489	52
142	1	440	489	489	49
143	0	0	0	0	0
144	1	444	489	489	45
145	1	447	477	477	30
146	2	456	477	489	33
147	2	458	489	498	40
148	2	462	489	498	36
149	0	0	0	0	0
150	1	468	483	483	15
151	0	0	0	0	0
152	1	477	489	489	12
153	2	479	489	498	19
154	1	483	498	498	15
155	0	0	0	0	0
156	0	0	0	0	0
157	0	0	0	0	0
158	0	0	0	0	0

Leaf Turnover Data for S2/23

a	b	c	d	e	f
1	2	23	57	98	75
2	2	28	89	98	70
3	2	35	63	98	63
4	3	41	70	98	57
5	2	44	72	98	54
6	3	47	98	119	72
7	1	50	98	98	48
8	7	55	98	119	64
9	1	57	103	103	46
10	3	61	103	119	58
11	3	63	107	126	63
12	3	65	116	116	51
13	5	68	126	148	80
14	3	70	144	158	88
15	2	72	133	158	86
16	6	76	144	158	82
17	8	82	126	148	66
18	3	84	133	141	57
19	3	89	133	144	55
20	3	92	138	146	54
21	4	98	138	144	46
22	1	100	144	144	44
23	3	103	144	153	50
24	4	105	144	153	48
25	1	107	144	144	37
26	6	112	144	158	46
27	2	114	144	158	44
28	2	117	144	158	41
29	2	119	144	158	39
30	3	124	144	158	34
31	6	126	144	158	32
32	2	128	144	173	45
33	10	132	144	173	41
34	12	134	144	173	39
35	6	138	165	176	38
36	8	141	158	179	38
37	2	144	151	173	29
38	3	146	179	186	40
39	3	148	154	186	38
40	5	151	158	193	42
41	4	153	193	221	68
42	9	155	193	207	52
43	7	158	193	207	49
44	6	160	207	230	70
45	2	162	207	207	45
46	2	165	207	214	49
47	4	167	207	214	47
48	6	169	193	207	38
49	9	172	207	214	42
50	6	174	216	223	49
51	4	176	207	214	38
52	6	179	207	218	39
53	2	181	207	207	26
54	6	183	214	221	38
55	12	186	207	221	35
56	13	189	230	251	62
57	8	193	216	256	63
58	8	195	230	256	61
59	3	197	221	256	59
60	25	207	230	270	63
61	9	209	242	263	54
62	3	211	249	256	45
63	5	214	235	256	42
64	4	216	242	256	40
65	3	218	242	260	42
66	12	221	242	263	42
67	6	223	249	263	40
68	7	225	249	256	31
69	11	230	249	263	33
70	9	232	249	263	31
71	6	235	256	274	39
72	5	237	263	280	43
73	3	239	256	293	54
74	1	242	293	293	51
75	1	244	278	278	34
76	2	246	270	278	32
77	7	249	278	321	72
78	14	251	278	321	70
79	14	253	300	323	70
80	13	256	278	356	100
81	8	258	314	360	102
82	5	260	314	363	103
83	6	263	278	356	93
84	4	265	356	370	105
85	2	267	278	330	63

a	b	c	d	e	f
86	5	270	284	370	100
87	1	272	356	356	84
88	6	277	335	370	93
89	3	279	377	384	105
90	0	0	0	0	0
91	2	284	370	384	100
92	0	0	0	0	0
93	2	293	335	370	77
94	2	297	370	370	73
95	2	300	370	370	70
96	5	302	363	384	82
97	1	304	377	377	73
98	1	307	391	391	84
99	6	309	370	405	96
100	0	0	0	0	0
101	8	314	383	426	112
102	4	316	384	440	124
103	6	318	370	422	104
104	8	321	356	405	84
105	7	323	356	433	110
106	3	325	398	405	80
107	4	330	391	422	92
108	6	332	363	398	66
109	3	335	384	405	70
110	7	337	391	433	96
111	4	339	391	422	83
112	14	356	370	405	49
113	8	358	391	426	68
114	5	360	398	426	66
115	11	363	384	447	84
116	16	365	391	447	82
117	4	367	405	422	55
118	7	370	398	426	56
119	4	372	426	440	68
120	2	374	447	447	73
121	7	377	426	440	63
122	11	379	405	440	61
123	3	381	447	468	87
124	4	384	405	447	63
125	2	386	433	447	61
126	2	388	433	477	89
127	1	391	456	456	65
128	3	393	447	447	54
129	1	395	477	477	82
130	3	398	456	456	58
131	0	0	0	0	0
132	0	0	0	0	0
133	1	405	447	447	42
134	2	409	447	447	38
135	0	0	0	0	0
136	1	422	447	447	25
137	4	426	447	477	51
138	3	428	477	489	61
139	0	0	0	0	0
140	2	433	498	498	65
141	7	437	447	483	46
142	7	440	447	504	64
143	5	442	483	498	56
144	3	444	498	504	60
145	10	447	477	498	51
146	8	456	468	511	55
147	4	458	489	525	67
148	7	462	489	511	49
149	3	464	498	504	40
150	4	468	483	504	36
151	6	471	489	511	40
152	7	477	498	519	42
153	4	479	504	519	40
154	9	483	498	525	42
155	10	486	511	525	39
156	6	489	511	532	43
157	6	493	519	525	32
158	12	498	525	532	34
159	3	500	525	525	25
160	3	504	525	532	28
161	3	507	532	532	25
162	7	511	532	539	28
163	7	514	532	539	25
164	20	517	532	545	28
165	9	521	545	560	39

Leaf Turnover Data for S2/78

a	b	c	d	e	f
1	2	23	57	98	75
2	2	28	70	98	70
3	2	35	72	98	63
4	3	41	76	98	57
5	1	44	98	98	54
6	1	47	105	105	58
7	2	50	98	105	55
8	4	55	98	105	50
9	1	57	107	107	50
10	3	61	98	112	51
11	2	63	114	119	56
12	4	65	107	124	59
13	3	69	107	132	63
14	3	70	114	138	68
15	2	72	105	141	69
16	5	76	117	126	50
17	6	82	119	138	56
18	2	84	138	151	67
19	2	89	126	165	76
20	1	92	165	165	73
21	5	98	132	153	55
22	1	100	155	155	55
23	2	103	141	148	45
24	2	105	148	158	53
25	2	107	144	158	51
26	6	112	153	173	61
27	1	114	165	165	51
28	2	117	146	165	48
29	2	119	165	179	60
30	4	124	165	173	49
31	4	126	173	195	69
32	4	128	173	179	51
33	5	132	165	173	41
34	4	134	165	193	59
35	6	138	165	193	55
36	3	141	186	207	66
37	5	144	186	193	49
38	2	146	186	193	47
39	1	148	186	186	38
40	4	151	207	214	63
41	2	153	214	221	68
42	3	155	214	221	66
43	4	158	214	221	63
44	3	160	221	221	61
45	2	162	214	221	59
46	2	165	221	221	56
47	1	167	214	214	47
48	2	169	207	207	38
49	2	172	214	221	49
50	2	174	207	207	33
51	2	176	207	221	45
52	3	179	207	221	42
53	2	181	221	221	40
54	2	183	221	270	87
55	1	186	221	221	35
56	3	189	230	270	81
57	4	193	256	263	70
58	2	195	263	278	83
59	2	197	230	235	38
60	9	207	230	278	71
61	3	209	242	278	69
62	2	211	263	263	52
63	3	214	263	278	64
64	1	216	249	249	33
65	4	218	263	278	60
66	0	0	0	0	0
67	3	223	263	278	55
68	2	225	263	263	38
69	5	230	270	284	54
70	2	232	263	278	46
71	2	235	270	270	35
72	1	237	270	270	33
73	1	239	263	263	24
74	2	242	278	278	36
75	3	244	278	286	42
76	2	246	278	293	47
77	2	249	270	278	29
78	3	251	278	307	56
79	6	253	278	335	82
80	11	256	307	335	79
81	3	258	307	330	72
82	6	260	356	440	180
83	11	263	300	363	100
87	2	265	363	363	98
85	3	267	339	363	96

a	b	c	d	e	f
86	7	270	335	363	93
87	7	272	339	363	91
88	6	277	339	377	100
89	2	279	330	377	98
90	1	281	377	377	96
91	1	284	377	377	93
92	2	286	339	363	77
93	3	293	339	363	70
94	3	297	356	363	66
95	4	300	363	377	77
96	1	302	356	356	54
97	0	0	0	0	0
98	0	0	0	0	0
99	0	0	0	0	0
100	4	311	363	422	111
101	5	314	370	440	126
102	0	0	0	0	0
103	1	318	426	426	108
104	0	0	0	0	0
105	4	323	363	456	133
106	0	0	0	0	0
107	3	330	398	447	117
108	3	332	370	377	45
109	4	335	377	412	77
110	5	337	377	440	103
111	6	339	384	422	83
112	13	356	377	447	91
113	4	358	377	391	33
114	6	360	391	447	87
115	5	363	440	456	93
116	0	0	0	0	0
117	1	367	447	447	80
118	3	370	447	462	92
19	8	372	440	462	90
120	6	374	440	477	103
121	10	377	440	489	112
122	2	379	433	447	68
123	1	381	422	422	41
124	1	384	398	398	14
125	0	0	0	0	0
126	0	0	0	0	0
127	6	391	426	468	77
128	2	393	477	483	90
129	2	395	447	447	52
130	4	398	447	468	70
131	4	400	440	468	68
132	3	402	447	468	66
133	0	0	0	0	0
134	1	409	483	483	74
135	1	412	456	456	44
136	4	422	456	486	64
137	15	426	468	504	78
138	6	428	468	483	55
139	3	430	477	500	70
140	3	433	489	525	92
141	8	437	477	500	63
142	6	440	468	489	49
143	2	442	477	489	47
144	2	444	477	483	39
145	4	447	477	489	42
146	4	456	483	539	83
147	3	458	468	483	25
148	5	462	483	483	21
149	4	464	489	498	34
150	5	468	483	489	21
151	4	471	498	498	27
152	6	477	498	517	40
153	0	0	0	0	0
154	6	483	498	511	28
155	5	486	504	525	39
156	4	489	511	525	36
157	7	493	511	525	32
158	7	498	525	545	47
159	2	500	525	525	25
160	2	504	525	532	28
161	5	507	525	545	38
162	2	511	532	539	28
163	7	514	539	545	31
164	5	517	539	545	28
165	6	521	545	545	24

Leaf turnover Data for S2/142

a	b	c	d	e	f
1	2	23	57	98	75
2	2	28	60	98	70
3	2	35	65	98	63
4	2	41	70	98	57
5	2	44	76	98	54
6	1	47	98	98	51
7	2	50	105	119	69
8	3	55	82	103	48
9	2	57	119	124	67
10	1	61	119	119	58
11	2	63	119	124	61
12	2	65	126	132	67
13	2	68	124	134	66
14	1	70	126	126	56
15	2	72	132	138	66
16	3	76	141	148	72
17	6	82	138	146	64
18	1	84	141	141	57
19	2	89	148	158	69
20	1	92	158	158	66
21	2	98	160	169	71
22	2	100	153	160	60
23	3	103	155	160	57
24	1	105	158	158	53
25	2	107	155	165	58
26	3	112	155	165	53
27	2	114	165	165	51
28	3	117	165	172	55
29	1	119	158	158	39
30	6	124	173	179	55
31	3	126	179	186	60
32	3	128	173	179	51
33	4	132	173	179	47
34	3	134	173	180	46
35	3	138	165	186	48
36	3	141	165	181	40
37	2	144	175	186	42
38	2	146	186	207	61
39	2	148	193	207	59
40	3	151	193	221	70
41	2	153	207	214	61
42	3	155	214	221	66
43	1	158	207	207	49
44	3	160	193	214	54
45	1	162	221	221	59
46	3	165	193	214	49
47	1	167	221	221	54
48	2	169	214	221	52
49	1	172	221	221	49
50	2	174	207	214	40
51	2	176	214	221	45
52	2	179	221	230	51
53	0	0	0	0	0
54	1	183	221	221	38
55	2	186	221	221	35
56	2	189	230	230	41
57	3	193	221	230	37
58	1	195	221	221	26
59	2	197	230	230	33
60	8	207	221	276	69
61	2	209	235	249	40
62	1	211	270	270	59
63	3	214	249	263	49
64	2	216	263	270	54
65	0	0	0	0	0
66	1	221	263	263	42
67	3	223	256	263	40
68	2	225	270	270	45
69	3	230	263	270	40
70	2	232	249	263	31
71	3	235	270	270	35
72	0	0	0	0	0
73	1	239	270	270	31
74	3	242	270	321	79
75	2	244	270	270	26
76	0	0	0	0	0
77	0	0	0	0	0
78	3	251	270	279	28
79	2	253	270	279	26
80	0	0	0	0	0
81	1	258	279	279	21
82	3	260	293	304	44
83	3	263	293	293	30
84	3	265	300	309	44
85	0	0	0	0	0

a	b	c	d	e	f
86	6	270	300	307	37
87	6	272	300	307	35
88	13	277	307	384	107
89	3	279	335	335	56
90	4	281	335	339	58
91	3	284	335	356	72
92	3	286	335	339	53
93	3	293	339	356	63
94	2	297	339	356	59
95	1	300	356	356	56
96	1	302	356	356	54
97	0	0	0	0	0
98	3	307	356	363	56
99	1	309	356	356	47
100	2	311	356	356	45
101	2	314	363	363	49
102	1	316	356	356	40
103	0	0	0	0	0
104	0	0	0	0	0
105	1	323	363	363	40
106	1	325	363	363	38
107	1	330	422	422	92
108	3	332	363	422	90
109	3	335	383	433	98
110	4	337	363	384	47
111	3	339	370	391	52
112	30	356	384	422	66
113	5	358	405	412	54
114	3	360	412	447	87
115	7	363	412	426	63
116	2	365	422	422	57
117	3	367	422	440	73
118	3	370	422	433	63
119	0	0	0	0	0
120	1	374	447	447	73
121	3	377	412	426	49
122	7	379	412	440	61
123	3	381	422	426	45
124	3	384	422	433	49
125	2	386	412	412	26
126	2	388	422	422	34
127	2	391	447	468	77
128	4	393	422	483	90
129	3	395	412	440	45
130	6	398	426	504	106
131	1	400	498	498	98
132	3	402	440	447	45
133	11	405	447	477	72
134	5	409	447	498	89
135	3	412	440	462	50
136	7	422	447	464	42
137	12	426	447	489	63
138	7	428	447	504	76
139	6	430	468	519	89
140	7	433	468	519	86
141	3	437	468	498	61
142	6	440	468	498	58
143	2	442	489	493	51
144	3	444	483	498	54
145	1	447	479	479	32
146	3	456	483	493	37
147	2	458	489	504	46
148	5	462	493	507	45
149	1	464	489	489	25
150	3	468	489	498	30
151	1	471	498	498	27
152	2	477	500	517	40
153	4	479	504	514	35
154	2	483	519	525	42
155	3	486	519	525	39
156	3	489	511	521	32
157	5	493	525	539	46
158	4	498	525	532	34
159	1	500	525	525	25
160	3	504	525	525	21
161	1	507	532	532	25
162	3	511	532	532	21
163	5	514	539	545	31
164	4	517	539	545	28
165	4	521	545	545	24

Leaf Turnover Data for S4/69

a	b	c	d	e	f
1	2	23	56	56	33
2	2	28	61	98	70
3	2	35	65	98	63
4	4	41	70	98	57
5	2	44	76	98	54
6	2	47	98	119	72
7	3	50	98	105	55
8	6	55	98	119	64
9	4	57	103	119	62
10	3	61	103	126	65
11	3	63	105	124	61
12	3	65	105	126	61
13	4	68	112	137	69
14	1	70	117	117	47
15	2	72	119	145	73
16	4	76	114	134	58
17	5	82	124	144	62
18	2	84	138	150	66
19	4	89	138	148	59
20	0	0	0	0	0
21	3	98	138	148	50
22	3	100	141	145	45
23	2	103	145	153	50
24	1	105	145	145	40
25	2	107	151	155	48
26	6	112	148	155	43
27	3	114	148	158	44
28	4	117	145	155	38
29	3	119	158	158	39
30	7	124	158	158	34
31	5	126	158	158	32
32	3	128	158	158	30
33	5	132	158	158	26
34	2	134	158	165	31
35	3	138	158	165	27
36	5	141	165	172	31
37	2	144	173	173	29
38	5	146	173	173	27
39	6	148	173	179	31
40	5	151	179	186	35
41	4	153	173	183	30
42	1	155	179	179	24
43	4	158	179	186	28
44	3	160	193	207	47
45	2	162	193	207	45
46	5	165	186	207	42
47	4	167	193	193	26
48	1	169	193	193	24
49	4	172	193	216	44
50	2	174	207	214	40
51	1	176	207	207	31
52	5	179	207	207	28
53	4	181	207	207	26
54	5	183	207	214	31
55	5	186	207	221	35
56	12	189	214	237	48
57	9	193	221	270	77
58	2	195	221	221	26
59	3	197	221	221	24
60	18	207	221	235	28
61	10	209	230	235	26
62	1	211	235	235	24
63	4	214	235	242	28
64	5	216	242	242	26
65	5	218	242	242	24
66	7	221	242	256	35
67	7	223	249	278	55
68	2	225	249	249	24
69	8	230	249	278	48
70	6	232	249	293	61
71	6	235	256	263	28
72	3	237	256	263	26
73	6	239	263	281	42
74	4	242	263	277	35
75	3	244	270	270	26
76	5	246	270	278	32
77	8	249	270	307	58
78	7	251	270	314	63
79	9	253	293	321	68
80	4	256	293	314	58
81	4	258	300	314	56
82	4	260	284	356	96
83	5	263	307	321	58
84	6	265	314	363	98
85	3	267	321	321	54
86	3	270	307	330	60
87	5	272	321	337	65
88	6	277	307	356	79
89	0	0	0	0	0
90	4	281	321	330	49
91	5	284	321	330	46
92	0	0	0	0	0
93	5	293	321	335	42
94	3	297	330	335	38
95	3	300	335	356	56
96	1	302	337	337	35
97	3	304	335	356	52
98	2	307	339	365	58
99	2	309	356	377	68
100	5	311	356	363	52
101	5	314	339	377	63
102	3	316	356	405	89
103	7	318	356	398	80
104	7	321	356	400	79
105	7	323	356	428	105
106	12	325	356	422	97
107	17	330	363	422	92
108	10	332	370	405	73
109	6	335	356	391	56
110	9	337	356	412	75
111	5	339	384	422	83
112	21	356	377	422	66
113	4	358	391	398	40
114	1	360	391	391	31
115	3	363	391	422	59
116	0	0	0	0	0
117	1	367	405	405	38
118	2	370	412	447	77
119	0	0	0	0	0
120	3	374	422	456	82
121	4	377	412	462	85
122	2	379	412	422	43
123	1	381	412	412	31
124	6	384	412	468	84
125	1	386	422	422	36
126	1	388	462	462	74
127	2	391	422	422	31
128	1	393	468	468	75
129	2	395	422	422	27
130	2	398	422	422	24
131	2	400	422	422	22
132	3	402	426	426	24
133	1	405	426	426	21
134	9	409	422	449	40
135	2	412	433	447	35
136	15	422	440	500	78
137	4	426	447	504	78
138	8	428	456	468	40
139	2	430	462	468	38
140	4	433	468	486	53
141	5	437	462	462	25
142	4	440	468	489	49
143	3	442	468	468	26
144	3	444	468	483	39
145	7	447	462	468	21
146	11	456	468	486	30
147	8	458	477	483	25
148	7	462	483	483	21
149	5	464	483	504	40
150	3	468	483	498	30
151	5	471	489	489	18
152	8	477	498	504	27
153	5	479	498	504	25
154	4	483	498	504	21
155	8	486	504	504	18
156	5	489	504	525	36
157	8	493	511	525	32
158	10	498	519	532	34
159	5	500	504	525	25
160	4	504	525	532	28
161	3	507	525	532	25
162	9	511	525	532	21
163	3	514	525	532	18
164	5	517	532	539	22
165	9	521	539	545	24

Leaf Turnover Data for S5/33

a	b	c	d	e	f
1	2	23	56	98	75
2	2	28	65	98	70
3	2	35	70	98	63
4	3	41	70	98	57
5	2	44	76	98	54
6	1	47	98	98	51
7	1	50	119	119	69
8	3	55	98	119	64
9	1	57	103	103	46
10	3	61	103	132	71
11	2	63	105	128	65
12	3	65	98	114	49
13	3	68	103	117	49
14	2	70	121	128	58
15	1	72	128	128	56
16	4	76	105	114	38
17	5	82	124	132	50
18	5	84	132	146	62
19	2	89	151	158	69
20	2	92	138	144	52
21	4	98	119	148	50
22	4	100	132	151	51
23	4	103	141	160	57
24	2	105	132	153	48
25	2	107	141	158	51
26	4	112	138	167	55
27	3	114	132	165	51
28	3	117	146	158	41
29	1	119	155	155	36
30	4	124	155	169	45
31	5	126	158	167	41
32	3	128	158	165	37
33	5	132	165	173	41
34	2	134	165	165	31
35	5	138	165	165	27
36	2	141	165	173	32
37	3	144	165	173	29
38	2	146	173	179	33
39	1	148	179	179	31
40	5	151	179	179	28
41	3	153	173	179	26
42	2	155	179	186	31
43	4	158	186	193	35
44	2	160	186	214	54
45	1	162	230	230	68
46	2	165	207	230	65
47	4	167	179	189	22
48	2	169	221	221	52
49	3	172	216	230	58
50	4	174	232	237	63
51	1	176	263	263	87
52	3	179	207	228	49
53	3	181	216	228	47
54	2	183	207	214	31
55	3	186	221	242	56
56	3	189	221	242	53
57	5	193	242	249	56
58	3	195	242	249	54
59	0	0	0	0	0
60	6	207	230	235	28
61	3	209	230	244	35
62	2	211	249	293	82
83	2	214	249	256	42
64	2	216	249	256	40
65	1	218	249	249	31
66	3	221	249	270	49
67	2	223	242	249	26
68	2	225	249	256	31
69	5	230	249	278	48
70	2	232	256	256	24
71	3	235	270	278	43
72	1	237	278	278	41
73	2	239	300	307	68
74	3	242	270	314	72
75	1	244	300	300	56
76	2	246	300	321	75
77	2	249	314	321	72
78	1	251	321	321	70
79	2	253	278	314	61
80	2	256	321	321	65
81	3	258	284	314	56
82	1	260	321	321	61
83	1	263	314	314	51
87	2	265	314	321	56
85	2	267	321	327	60
86	2	270	321	321	51
87	1	272	321	321	49
88	2	277	321	321	44
89	0	0	0	0	0
90	0	0	0	0	0
91	3	284	321	337	53
92	0	0	0	0	0
93	3	293	321	321	28
94	3	297	330	335	38
95	3	300	330	335	35
96	0	0	0	0	0
97	1	304	335	335	31
98	2	307	335	339	32
99	2	309	356	356	47
100	0	0	0	0	0
101	4	314	356	356	42
102	0	0	0	0	0
103	1	318	356	356	38
104	3	321	356	370	49
105	1	323	370	370	47
106	0	0	0	0	0
107	4	330	363	370	40
108	4	332	363	377	45
109	1	335	377	377	42
110	3	337	377	384	47
111	0	0	0	0	0
112	6	356	384	389	33
113	3	358	389	412	54
114	0	0	0	0	0
115	1	363	391	391	28
116	3	365	391	405	40
117	1	367	412	412	45
118	1	370	433	433	63
119	1	372	440	440	68
120	2	374	440	447	73
121	1	377	440	440	63
122	2	379	433	440	61
123	1	381	440	440	59
124	1	384	440	440	56
125	1	386	440	440	54
136	2	388	440	440	52
127	1	391	447	447	56
128	1	393	477	477	84
129	1	395	440	440	45
130	1	398	433	433	35
131	2	400	433	440	40
132	0	0	0	0	0
133	1	405	440	440	35
134	2	409	440	447	38
135	1	412	440	440	28
136	6	422	447	462	40
137	3	426	456	462	36
138	0	0	0	0	0
139	1	430	468	468	38
140	3	433	462	483	50
141	2	437	468	477	40
142	1	440	468	468	28
143	2	442	477	477	35
144	2	444	477	489	45
145	1	447	489	489	42
146	4	456	483	489	33
147	1	458	489	489	31
148	3	462	489	498	36
149	1	464	498	498	34
150	1	468	498	498	30
151	3	471	498	498	27
152	2	477	511	517	40
153	0	0	0	0	0
154	3	483	525	532	49
155	3	486	511	525	39
156	2	489	525	525	36
157	3	493	525	532	39
158	3	498	525	525	27
159	2	500	519	525	25
160	3	504	532	539	35
162	2	507	532	539	32
162	1	511	560	560	49
163	2	514	539	560	46
164	3	517	554	560	43
165	3	521	554	560	39

Leaf Turnover Data for S5/43

a	b	c	d	e	f
1	2	23	57	89	66
2	2	28	65	98	70
3	2	35	70	98	63
4	5	41	76	98	57
5	2	44	82	98	54
6	2	47	81	105	58
7	2	50	82	105	55
8	6	55	98	119	64
9	1	57	105	105	48
10	2	61	119	128	67
11	3	63	116	126	63
12	5	65	107	126	61
13	2	68	103	128	60
14	3	70	107	137	67
15	3	72	116	132	60
16	3	76	107	127	51
17	7	82	123	158	76
18	4	84	126	148	64
19	3	89	114	134	45
20	1	92	119	119	27
21	5	98	124	148	50
22	1	100	141	141	41
23	2	103	128	158	55
24	3	105	138	165	60
25	3	107	138	169	62
26	3	112	144	173	61
27	3	114	144	173	59
28	2	117	126	168	51
29	0	0	0	0	0
30	5	124	141	158	34
31	2	126	144	173	47
32	3	128	144	173	45
33	4	132	155	168	36
34	2	134	151	168	34
35	5	138	158	173	35
36	5	141	146	165	24
37	4	144	165	173	29
38	4	146	173	189	43
39	4	148	176	193	45
40	2	151	186	186	35
41	1	153	214	214	61
42	4	155	179	230	75
43	1	158	214	214	56
44	5	160	214	230	70
45	0	0	0	0	0
46	4	165	207	221	56
47	2	167	207	218	51
48	1	169	207	207	38
49	3	172	207	219	47
50	3	174	207	207	33
51	2	176	207	230	54
52	2	179	207	214	35
53	2	181	207	214	33
54	2	183	207	207	24
55	3	186	207	214	28
56	4	189	214	221	32
57	4	193	221	253	60
56	3	195	214	278	83
59	3	197	230	255	58
60	8	207	230	242	35
61	4	209	230	242	33
62	1	211	235	235	24
83	2	214	242	242	28
64	3	216	242	242	26
65	4	218	242	278	60
66	1	221	278	278	57
67	2	223	278	278	55
68	3	225	278	278	53
69	3	230	356	378	148
70	1	232	278	278	46
71	3	235	270	330	95
72	1	237	270	270	33
73	3	239	270	286	47
74	1	242	278	278	36
75	4	244	270	293	49
76	1	246	278	278	32
77	5	249	284	316	67
78	1	251	330	330	79
79	3	253	278	284	31
80	1	256	293	293	37
81	6	258	293	321	63
82	2	260	293	316	56
83	2	263	339	358	95
84	0	0	0	0	0
85	2	267	284	284	17

a	b	c	d	e	f
86	0	0	0	0	0
87	3	272	321	330	58
88	3	277	321	330	53
89	0	0	0	0	0
90	1	281	356	356	75
91	1	284	330	330	46
92	2	286	330	356	70
93	4	293	330	330	37
94	4	297	330	330	33
95	0	0	0	0	0
96	3	302	330	335	33
97	2	304	330	330	26
98	0	0	0	0	0
99	1	309	339	339	30
100	0	0	0	0	0
101	1	314	337	337	23
102	4	316	330	358	42
103	1	318	358	358	40
104	3	321	358	412	91
105	2	323	358	358	35
106	1	325	358	358	33
107	2	330	358	358	28
108	5	332	358	377	45
109	5	335	358	365	30
110	3	337	370	377	40
111	3	339	363	391	52
112	8	356	370	433	77
113	1	358	440	440	82
114	1	368	426	426	58
115	4	363	370	412	49
116	0	0	0	0	0
117	3	367	412	422	55
118	1	370	412	412	42
119	0	0	0	0	0
120	1	374	405	405	31
121	3	377	405	412	35
122	1	379	433	433	54
123	0	0	0	0	0
124	2	384	422	468	84
125	2	386	422	426	40
126	1	388	468	468	80
127	2	391	394	426	35
128	1	393	422	422	29
129	1	395	422	422	27
130	4	398	412	433	35
131	0	0	0	0	0
132	3	402	440	468	66
133	0	0	0	0	0
134	2	409	462	466	57
135	1	412	447	447	35
136	6	422	440	477	55
137	3	426	456	468	42
138	0	0	0	0	0
139	2	430	447	447	17
140	1	433	468	468	35
141	3	437	462	480	43
142	2	440	462	462	22
143	2	442	468	501	59
144	1	444	498	498	54
145	1	447	462	462	15
146	4	456	483	498	42
147	3	458	477	498	40
148	1	462	489	489	27
149	1	464	498	498	34
150	1	468	489	489	21
151	4	471	483	498	27
152	3	477	498	532	55
153	0	0	0	0	0
154	2	483	511	525	42
155	3	486	498	532	46
156	2	489	498	539	50
157	3	493	511	532	39
158	5	498	525	545	47
159	3	500	519	539	39
160	1	504	532	532	28
161	2	507	532	545	38
162	1	511	545	545	34
163	1	514	545	545	31
164	2	517	539	545	28
165	0	0	0	0	0

Appendix IV Flowering Sequence Data

The columns from the left represent: plant age in days, total number of achenes produced, number of empty achenes, total weight of achenes (g), mean weight of achenes (mg) and, number of viable achenes. Plant code and achene weight of plant (mg) are given by the side.

120	376	75	0.2264	0.6021	301	
126	403	72	0.2104	0.5221	331	
127	392	30	0.2502	0.6383	362	
128	365	42	0.2292	0.6279	323	
182	175	31	0.0840	0.4800	144	
186	168	46	0.0604	0.3595	122	
189	176	18	0.0713	0.4051	158	W1/15 0.4626mg
193	147	25	0.0537	0.3653	122	
196	148	19	0.0690	0.4662	129	
197	159	35	0.0719	0.4522	124	
217	149	41	0.0748	0.5020	108	
317	126	9	0.0766	0.6079	117	
435	195	14	0.1339	0.6867	181	
525	198	30	0.0902	0.4556	168	
534	138	33	0.5660	0.4058	105	

120	333	68	0.1937	0.5817	265	
125	287	78	0.1500	0.5226	209	
126	308	78	0.1682	0.5461	230	
127	336	67	0.1680	0.5000	269	
128	314	47	0.1589	0.5061	267	
133	306	130	0.0807	0.2637	176	W1/24 0.5202mg
176	158	42	0.0450	0.2848	116	
184	174	59	0.0766	0.4402	115	
196	198	87	0.0394	0.1990	111	
228	122	48	0.0639	0.5238	74	
252	137	66	0.0342	0.2496	71	
378	140	23	0.0796	0.5686	117	
417	121	42	0.0603	0.4983	79	
450	138	15	0.0245	0.1775	123	

120	361	38	0.2514	0.6964	323	
126	302	61	0.1845	0.6109	241	
127	323	39	0.1859	0.5732	284	
129	305	69	0.1740	0.5705	236	
130	322	51	0.1872	0.5814	271	
140	286	69	0.1823	0.6374	217	
144	244	97	0.0432	0.1771	147	
186	178	26	0.1009	0.5669	152	
196	138	41	0.0516	0.3739	97	
196	173	30	0.0732	0.4231	143	W1/70 0.7447mg
200	149	24	0.0636	0.4268	125	
219	99	38	0.0487	0.4919	61	
225	111	43	0.0338	0.3045	68	
228	131	46	0.0569	0.4344	85	
252	113	42	0.0464	0.4106	71	
263	112	24	0.0616	0.5500	88	
301	168	35	0.0902	0.5369	133	
408	153	36	0.0223	0.1458	117	
440	144	35	0.0728	0.5056	109	
179	127	25	0.0623	0.4906	102	
532	111	36	0.0288	0.2595	75	

120	338	67	0.2058	0.6089	271	
126	322	72	0.1632	0.5068	250	
127	333	79	0.1587	0.4766	254	
128	331	46	0.1954	0.5903	285	
129	335	43	0.1994	0.5952	292	
134	319	75	0.1540	0.4828	244	W1/83 0.7741mg
184	134	23	0.0591	0.4410	111	
192	163	45	0.0772	0.4736	118	
193	130	25	0.0407	0.3131	105	
214	93	32	0.0297	0.3194	61	
385	94	1	0.0771	0.8202	93	
399	138	13	0.0685	0.4986	125	
508	159	30	0.0744	0.4679	129	

129	404	84	0.2316	0.5733	320	
133	295	77	0.0610	0.2068	218	
140	344	69	0.1084	0.3151	275	
147	289	116	0.0719	0.2488	173	
155	289	156	0.0245	0.0848	133	
176	137	54	0.0519	0.3788	83	
203	123	52	0.0522	0.4244	71	
211	134	68	0.0502	0.3746	66	
378	211	10	0.1128	0.5376	201	W1/93 0.7913mg
399	168	7	0.0985	0.5863	161	
404	188	4	0.0951	0.5059	184	
434	202	19	0.1046	0.5178	183	
439	162	24	0.0253	0.1562	138	
444	169	3	0.0876	0.5183	166	
464	432	11	0.0797	0.6038	121	
478	169	53	0.0814	0.4817	116	
479	166	32	0.0833	0.5015	134	
497	130	2	0.0210	0.1615	128	
498	103	5	0.0151	0.1466	98	

127	377	80	0.1994	0.5289	297	
132	309	128	0.1130	0.3657	181	
133	334	90	0.1328	0.3976	244	
134	297	68	0.1281	0.4357	229	
140	319	63	0.1764	0.5517	256	
142	332	28	0.1557	0.4689	304	
149	272	123	0.0424	0.1559	149	
155	285	128	0.0945	0.3316	157	
176	203	93	0.0226	0.1113	110	W1/114 0.8569mg
182	152	27	0.0816	0.5368	125	
183	139	38	0.0687	0.4942	101	
185	135	39	0.0609	0.4511	96	
207	118	21	0.0601	0.5093	97	
211	152	54	0.0690	0.4539	98	
224	129	61	0.0476	0.3690	68	
228	148	79	0.0433	0.2926	69	
280	146	69	0.0587	0.4021	77	
351	160	46	0.0694	0.4338	114	
378	119	14	0.0721	0.6059	105	
430	144	52	0.0703	0.4882	92	

126	389	46	0.2528	0.6499	343	
127	315	62	0.1607	0.5102	253	
128	302	55	0.1432	0.4742	247	
130	313	83	0.1559	0.4981	230	
133	340	105	0.1618	0.4759	235	
134	325	83	0.1395	0.4293	242	
142	251	80	0.0437	0.1741	171	
147	303	115	0.1127	0.3719	188	
182	117	9	0.0732	0.6256	108	W1/115 0.8573mg
224	128	80	0.0280	0.2188	48	
238	114	7	0.0211	0.1851	107	
252	117	30	0.0137	0.1171	87	
277	95	7	0.0610	0.6326	88	
351	133	13	0.0732	0.5504	120	
406	106	26	0.0492	0.4642	80	
415	111	30	0.0237	0.2151	81	
416	161	18	0.0205	0.1273	143	
528	143	62	0.0385	0.2692	81	
545	88	29	0.0361	0.4102	59	

126	335	75	0.1830	0.5463	260	
127	289	72	0.1339	0.4633	217	
128	314	55	0.1676	0.5338	259	
129	299	42	0.1473	0.4926	257	
130	311	72	0.1630	0.5241	239	
133	325	96	0.1330	0.4092	229	
140	274	76	0.0492	0.1796	198	W1/116 0.8589mg
150	218	81	0.0339	0.1555	137	
186	145	101	0.0119	0.0821	44	
371	95	7	0.0612	0.6442	88	
399	129	8	0.0260	0.2016	121	
404	129	16	0.0769	0.5961	113	
439	124	20	0.0528	0.4258	104	
489	462	12	0.0799	0.4932	450	
495	162	24	0.0558	0.3444	138	

120	357	70	0.2054	0.5754	287	
126	290	58	0.1501	0.5207	232	
128	354	81	0.1776	0.5017	273	
129	361	103	0.1769	0.4900	258	
130	350	72	0.1874	0.5354	278	
133	351	84	0.1548	0.4410	267	
134	333	101	0.1444	0.4336	232	
149	282	60	0.1387	0.4918	222	
155	214	100	0.0218	0.1019	114	
164	125	32	0.0124	0.0992	93	
170	179	45	0.0573	0.3201	134	W1/136 0.9255mg
177	126	38	0.0461	0.3659	88	
178	179	86	0.0365	0.2039	93	
184	133	37	0.0591	0.4444	96	
185	113	35	0.0466	0.4124	78	
192	142	39	0.0664	0.4676	103	
196	129	24	0.0555	0.4302	105	
203	114	22	0.0547	0.4798	92	
218	147	50	0.0784	0.5333	97	
240	134	40	0.0176	0.1313	94	
280	127	43	0.0436	0.3433	84	
287	120	41	0.0480	0.4000	79	
301	112	42	0.0164	0.1464	70	
440	136	24	0.0297	0.2285	112	

126	429	69	0.2437	0.5681	360	
129	354	58	0.1781	0.5031	296	
133	347	71	0.1511	0.4355	276	
134	331	52	0.1404	0.4242	279	
140	318	68	0.1688	0.5308	250	W1/139 0.9340mg
147	297	52	0.1606	0.5407	245	
189	164	53	0.0793	0.4835	111	
507	140	38	0.0601	0.4293	102	
537	128	40	0.0172	0.1344	88	
377	303	6	0.1984	0.6548	297	
378	161	9	0.0792	0.4919	152	
380	135	9	0.0620	0.4593	126	W2/114 0.9725mg
381	185	3	0.1064	0.5751	182	
382	185	7	0.0948	0.5124	178	
383	119	10	0.0224	0.1882	109	
384	138	6	0.0924	0.6696	132	
377	415	44	0.2397	0.5776	371	
378	141	3	0.1065	0.7533	138	
399	156	5	0.1110	0.7115	151	
380	174	5	0.1340	0.7701	169	W2/125 1.0151mg
382	135	13	0.0292	0.2163	122	
384	184	4	0.1316	0.7152	180	
385	175	8	0.0966	0.5520	167	
390	148	16	0.0813	0.5493	132	
391	206	9	0.0883	0.4286	197	
390	162	12	0.0406	0.2506	150	W2/166 1.1643mg
396	194	18	0.0316	0.1629	176	
380	343	25	0.2199	0.6411	318	
381	169	5	0.1305	0.7722	164	W2/168 1.1717mg
383	154	5	0.0513	0.3331	149	
390	185	7	0.1121	0.6059	178	
391	201	13	0.0936	0.4657	188	
380	185	15	0.0943	0.5097	170	
381	194	7	0.1148	0.5918	187	
382	167	15	0.0949	0.5683	152	W2/189 1.2255mg
383	120	2	0.0235	0.1958	118	
384	150	10	0.0344	0.2293	140	
385	200	4	0.0465	0.2325	196	
386	139	8	0.0309	0.2223	131	
129	480	31	0.2600	0.5417	449	
135	316	25	0.1320	0.4177	291	
136	331	14	0.1580	0.4773	317	
138	328	21	0.1560	0.4756	307	W3/20 0.4623mg
198	147	5	0.0569	0.3871	142	
203	134	9	0.0611	0.4560	125	
228	140	5	0.0728	0.5200	135	
270	62	5	0.0176	0.2839	57	
395	169	2	0.0607	0.3592	167	

130	446	28	0.1871	0.4195	418	
142	306	32	0.1140	0.3725	274	
143	318	43	0.1328	0.4176	275	
144	305	44	0.1166	0.3823	261	
224	143	11	0.0408	0.2853	132	
228	102	7	0.0220	0.2157	95	
238	110	2	0.0566	0.5145	108	W3/43 0.6244mg
240	92	12	0.0369	0.4011	80	
252	95	12	0.0127	0.1337	83	
261	90	4	0.0471	0.5233	86	
262	107	6	0.0485	0.4533	101	
263	93	10	0.0386	0.4151	83	
406	184	8	0.0511	0.4408	176	
417	164	3	0.0757	0.4616	161	
498	124	6	0.0305	0.2460	118	

133	364	24	0.1912	0.5232	340	
139	254	16	0.1114	0.4386	238	
140	273	7	0.1370	0.5018	266	
141	294	9	0.1311	0.4459	285	
142	247	8	0.1102	0.4462	239	
147	251	25	0.1146	0.4566	226	W3/58 0.6828mg
259	128	5	0.0547	0.4273	123	
261	115	7	0.0574	0.4470	108	
294	62	1	0.0316	0.5097	61	
301	92	2	0.0441	0.4793	90	
346	70	0	0.0395	0.5643	70	
352	83	0	0.0364	0.4386	83	

133	395	15	0.1920	0.4861	380	
143	238	30	0.1062	0.4462	208	
147	255	32	0.0941	0.3690	223	
148	204	20	0.0913	0.3742	184	
150	264	21	0.0946	0.3583	243	
155	253	20	0.0933	0.3688	233	
196	136	6	0.6000	0.4412	130	W3/101 0.7681mg
210	120	0	0.0621	0.5175	120	
219	132	4	0.0610	0.4621	128	
242	117	6	0.0507	0.4333	111	
243	175	6	0.0739	0.4223	169	
289	92	4	0.0481	0.5228	88	
305	88	1	0.0457	0.5193	87	
350	96	2	0.0394	0.4104	94	
549	467	26	0.0459	0.2749	441	

133	415	23	0.2144	0.5166	392	
147	271	31	0.1128	0.4162	240	
148	290	31	0.1248	0.4303	259	
154	282	29	0.1122	0.3979	253	
155	282	43	0.0990	0.3511	239	
156	283	14	0.1126	0.3979	269	W3/120 0.7928mg
240	109	3	0.0511	0.4688	106	
242	154	11	0.0698	0.4532	143	
251	127	4	0.0621	0.4890	123	
252	112	10	0.0492	0.4393	102	
253	135	15	0.0607	0.4496	120	
259	70	13	0.0250	0.3751	57	
447	85	0	0.0331	0.3894	85	
464	131	6	0.0414	0.3160	125	

133	429	34	0.2028	0.4620	395	
140	290	45	0.1137	0.3921	245	
142	290	34	0.1376	0.4745	256	
143	288	46	0.1058	0.3674	242	
150	269	59	0.0741	0.2755	210	
219	131	5	0.0622	0.4748	126	W3/127 0.8039mg
287	112	5	0.0540	0.4821	107	
301	85	3	0.0398	0.4682	82	
359	102	6	0.0426	0.4176	96	
378	90	2	0.0412	0.4578	88	
395	103	2	0.0574	0.5573	101	

133	446	46	0.1751	0.3926	400	
140	320	23	0.1391	0.4347	297	
141	271	38	0.1007	0.3716	233	
142	309	35	0.1299	0.4204	274	
143	327	29	0.1419	0.4339	298	W3/140 0.8235mg
147	312	40	0.1241	0.3978	272	
214	170	9	0.0727	0.4276	161	
235	146	6	0.0663	0.4541	140	
236	117	9	0.0424	0.3624	108	
260	108	4	0.0338	0.3102	104	

133	389	23	0.1970	0.5064	366	
142	268	23	0.1226	0.4575	245	
144	259	40	0.1032	0.3985	219	
147	252	38	0.1115	0.4425	214	W3/149 0.8443mg
155	255	21	0.1043	0.4090	234	
228	129	3	0.0371	0.2876	126	
235	117	4	0.0624	0.5333	113	
261	132	12	0.0681	0.5159	120	
294	63	2	0.0328	0.5206	61	

134	446	28	0.2052	0.4601	418	
142	274	27	0.0889	0.3245	247	
147	274	38	0.0558	0.2036	236	
148	279	51	0.0899	0.3222	228	
150	266	18	0.1000	0.3763	248	
190	156	17	0.0247	0.1583	139	
198	136	5	0.0675	0.4963	131	
210	119	8	0.0424	0.3563	111	W3/150 0.8482mg
224	110	13	0.0153	0.1391	97	
352	114	7	0.0497	0.4360	107	
380	85	5	0.0490	0.5765	80	
395	113	4	0.0520	0.4602	109	
504	159	5	0.0544	0.3421	154	
507	191	12	0.0541	0.2852	179	

356	188	10	0.0981	0.5218	178	
401	156	8	0.0721	0.4622	148	
428	99	3	0.0343	0.3465	96	
430	121	3	0.0478	0.3950	118	
431	120	21	0.0253	0.2108	99	W4/37 0.5387mg
432	121	8	0.0379	0.3132	113	
433	92	5	0.0246	0.2674	87	
434	88	9	0.0256	0.2909	79	
435	146	23	0.0130	0.0890	123	
436	112	5	0.0310	0.2768	107	
438	93	10	0.0263	0.2828	83	
468	74	2	0.0379	0.5122	72	

399	165	5	0.1154	0.6994	160	
425	111	3	0.0585	0.5270	108	
416	102	2	0.0547	0.5363	100	
418	109	3	0.0579	0.5413	106	W4/69 0.6610mg
421	109	3	0.0549	0.5037	106	
434	130	4	0.0701	0.5392	126	
436	127	4	0.0736	0.5795	123	
437	111	10	0.0628	0.5658	10[illegible]	

428	402	68	0.1494	0.3716	334	
431	143	15	0.0880	0.6154	128	
443	147	2	0.0878	0.5973	145	
445	94	4	0.0523	0.5564	90	W4/72 0.6690mg
448	114	2	0.0624	0.5474	112	
449	98	1	0.0554	0.5653	97	
450	141	14	0.0683	0.4844	127	
454	132	10	0.0636	0.4818	122	
455	107	12	0.0446	0.4168	95	

418	431	52	0.1717	0.3984	379	
423	218	4	0.1255	0.5757	214	W4/102 0.7362mg
430	152	5	0.0733	0.4822	147	
432	133	5	0.0747	0.5617	128	
438	121	1	0.0728	0.6017	120	

430	172	8	0.0591	0.3436	164	
438	145	3	0.0985	0.6793	142	W4/118 0.7721mg
454	124	4	0.0850	0.6855	120	
455	113	3	0.0765	0.6770	110	

428	93	3	0.0422	0.4538	90	
429	103	3	0.0372	0.3612	100	
430	107	3	0.0378	0.3533	104	
431	142	8	0.0507	0.3570	134	
432	119	5	0.0395	0.3319	114	
433	110	7	0.0445	0.4045	103	W4/160 0.8678mg
434	113	6	0.0420	0.3717	107	
435	83	9	0.0139	0.1675	74	
436	123	15	0.0145	0.1179	108	
438	102	0	0.0144	0.1412	102	
490	138	9	0.1221	0.8848	129	
520	175	13	0.0950	0.5429	162	

411	456	46	0.1805	0.3958	410	
414	273	36	0.1248	0.4571	237	W4/171 0.9002mg
438	151	4	0.0199	0.1318	147	
445	125	4	0.0672	0.4976	121	

409	256	5	0.1944	0.6797	251	
418	133	3	0.0664	0.4992	130	
419	95	7	0.0334	0.3516	88	
425	157	12	0.0202	0.1287	145	W4/174 0.9097mg
430	165	13	0.0184	0.1179	152	
432	146	23	0.0286	0.1959	123	
434	88	4	0.0389	0.3284	84	
437	346	29	0.1871	0.5408	317	
439	159	23	0.0219	0.1377	136	

430	203	13	0.1058	0.5212	190	
432	236	18	0.1038	0.4398	218	W4/196 1.1182mg
435	126	7	0.0720	0.5714	119	

127	478	29	0.2218	0.4640	449	
133	344	42	0.1188	0.3453	302	
133	312	17	0.1322	0.4237	295	
134	349	34	0.1348	0.3862	315	
140	316	25	0.1534	0.4854	291	
141	116	11	0.0455	0.3922	105	
155	270	26	0.1350	0.5000	244	W5/14 0.3825mg
254	86	3	0.0452	0.5256	83	
258	102	16	0.0430	0.4216	86	
259	93	29	0.0303	0.3258	64	
260	97	6	0.0389	0.4010	91	
261	91	2	0.0340	0.3736	89	
263	120	11	0.0509	0.4242	109	
268	112	4	0.0471	0.4205	108	
301	102	5	0.0354	0.3471	97	
126	429	27	0.2291	0.5340	402	
130	384	32	0.1706	0.4443	352	
133	381	40	0.1696	0.4451	341	
134	375	25	0.1738	0.4635	350	
140	348	34	0.1774	0.5098	314	
226	159	5	0.0740	0.4654	154	W5/19 0.4637mg
228	124	5	0.0487	0.3927	119	
238	139	7	0.0615	0.4424	132	
242	79	1	0.0345	0.4367	78	
266	82	4	0.0433	0.5280	78	
277	42	0	0.0227	0.5405	42	
444	201	9	0.0853	0.4244	192	
448	120	4	0.0482	0.4017	116	
126	463	41	0.2078	0.4488	422	
129	379	44	0.1537	0.4055	335	
130	391	28	0.1539	0.3936	363	
133	366	40	0.1386	0.3787	326	
136	322	22	0.1370	0.4255	300	W5/29 0.5173mg
156	295	29	0.1216	0.4122	266	
240	158	8	0.0681	0.4310	150	
252	90	11	0.0428	0.4756	79	
259	155	9	0.0705	0.4549	146	
275	76	2	0.0358	0.4711	74	
284	43	5	0.0233	0.5419	38	
347	98	1	0.0483	0.4929	97	
128	483	34	0.2218	0.4592	449	
136	310	45	0.1205	0.3887	265	
140	311	26	0.1466	0.4714	285	
143	302	26	0.1243	0.4116	276	W5/33 0.5290mg
224	202	5	0.1027	0.5084	197	
291	75	0	0.0327	0.4360	75	
476	143	11	0.0526	0.3678	132	
245	92	77	0.0179	0.1946	15	M1/23 0.6243mg
464	79	5	0.0386	0.4886	74	
224	83	5	0.0129	0.1506	78	M1/31 0.6986mg
245	77	11	0.0239	0.3104	66	
234	90	3	0.0497	0.5522	87	
243	101	2	0.0572	0.5663	99	M1/74 0.7984mg
468	129	4	0.0969	0.7512	125	

243	141	6	0.1050	0.7447	135	
254	96	20	0.0296	0.3083	76	M1/115 0.8665mg
256	154	27	0.0378	0.2455	127	

226	120	1	0.0625	0.5208	119	
227	119	3	0.0556	0.4672	116	M1/116 0.8667mg
228	78	12	0.0042	0.0538	66	

234	99	0	0.0197	0.1990	99	
238	136	7	0.0228	0.1676	129	
240	81	2	0.0090	0.1111	79	M1/118 0.8736mg
243	127	2	0.0753	0.5929	125	
277	91	6	0.0145	0.1593	85	

234	95	12	0.0177	0.1863	83	
238	94	9	0.0199	0.2117	85	M1/119 0.8811mg
242	109	2	0.0674	0.6183	107	
261	73	1	0.0535	0.7329	72	

214	237	1	0.1555	0.6561	236	
228	134	7	0.0473	0.3530	127	
231	92	13	0.0158	0.1717	79	M1/136 0.9542mg
252	95	4	0.0098	0.1032	91	
475	112	2	0.0838	0.7482	110	
489	105	1	0.0675	0.6429	104	

126	385	29	0.1710	0.4442	356	
127	364	25	0.1771	0.4865	339	
130	371	14	0.1785	0.4811	357	
133	366	22	0.1870	0.5109	344	
134	364	11	0.1688	0.4637	353	
140	320	19	0.1634	0.5106	301	M2/21 0.4297mg
163	222	29	0.0853	0.3842	193	
221	118	7	0.0516	0.4288	111	
252	123	18	0.0530	0.4309	105	
277	110	2	0.0644	0.5855	108	
289	67	0	0.0376	0.5612	67	
329	78	0	0.0414	0.5308	78	
552	102	0	0.0417	0.4088	102	

126	466	42	0.2415	0.5182	424	
127	355	25	0.1801	0.5099	330	
130	363	21	0.1954	0.5383	342	
133	360	25	0.1829	0.5081	335	
134	334	28	0.1704	0.5102	306	
136	307	42	0.1500	0.4886	265	
155	243	22	0.1307	0.5379	221	
183	98	1	0.0264	0.2694	97	M2/26 0.4392mg
231	179	12	0.0609	0.3402	167	
254	126	1	0.0604	0.4794	125	
259	78	7	0.0298	0.3821	71	
296	73	0	0.0243	0.3329	73	
317	84	5	0.0352	0.4190	79	
420	106	3	0.0474	0.4472	103	
427	64	1	0.0321	0.5016	63	
445	83	1	0.0430	0.5181	82	
448	105	0	0.0485	0.4619	105	

126	453	41	0.2377	0.5247	412	
133	329	40	0.1424	0.4328	289	
134	353	51	0.1541	0.4365	302	
140	314	13	0.1564	0.4981	301	
141	306	16	0.1498	0.4895	290	
210	328	16	0.1602	0.4884	312	M2/36 0.4842mg
226	117	8	0.0530	0.4530	109	
234	114	0	0.0561	0.4921	114	
291	131	3	0.0144	0.1099	128	
465	131	7	0.0510	0.3893	124	
504	155	5	0.0625	0.4032	150	

126	477	27	0.2483	0.5205	450	
129	363	23	0.1784	0.4915	340	
130	375	30	0.1765	0.4707	345	
132	366	22	0.1762	0.4814	344	
133	369	9	0.1959	0.5309	360	
140	328	24	0.1654	0.5043	304	
217	142	13	0.0351	0.2422	129	
224	108	4	0.0590	0.5463	104	
233	98	3	0.0567	0.5786	95	M2/46 0.5456mg
234	107	2	0.0547	0.5112	105	
251	84	2	0.0465	0.5536	82	
252	77	7	0.0419	0.5442	70	
284	89	5	0.0415	0.4663	84	
303	102	0	0.0592	0.5804	102	
317	52	2	0.0323	0.6212	50	
329	103	3	0.0547	0.5311	100	
352	75	4	0.0446	0.5947	71	

120	411	33	0.2012	0.4895	378	
126	400	27	0.2114	0.5285	373	
128	389	18	0.1937	0.4979	371	
129	410	26	0.2048	0.4995	384	
130	400	19	0.1977	0.4943	381	M2/49 0.5548mg
134	332	10	0.1598	0.4813	322	
142	275	23	0.1212	0.4407	252	
266	47	0	0.0275	0.5851	47	
280	84	3	0.0465	0.5565	81	
291	90	2	0.0390	0.4333	88	
504	178	11	0.0680	0.3820	167	

126	411	35	0.2249	0.5472	376	
128	309	18	0.1474	0.4771	291	
129	363	18	0.1884	0.5190	345	
130	340	24	0.1718	0.5053	316	
133	365	35	0.1756	0.4811	330	
134	342	16	0.1816	0.5310	326	
142	267	7	0.1484	0.5558	260	
154	176	12	0.0782	0.4443	164	M2/59 0.5939mg
155	147	7	0.0399	0.2720	140	
168	111	10	0.0493	0.4441	101	
218	126	7	0.0557	0.4421	119	
221	128	2	0.0754	0.5891	126	
254	98	2	0.0543	0.5541	96	
420	125	5	0.0331	0.2648	120	
427	123	5	0.0262	0.2130	118	

126	372	30	0.1922	0.5167	342	
132	338	18	0.1429	0.4228	320	
133	312	28	0.1176	0.3769	284	
134	322	24	0.1296	0.4025	298	M2/104 0.6597mg
136	335	27	0.1586	0.4734	308	
140	322	26	0.1453	0.4512	296	
142	298	20	0.1407	0.4728	278	
240	135	14	0.0448	0.3319	121	
254	36	3	0.0168	0.4667	33	

126	438	30	0.2196	0.5014	408	
127	386	24	0.1687	0.4370	362	
128	345	26	0.1597	0.4629	319	
130	366	31	0.1777	0.4855	335	
131	380	34	0.1740	0.4484	346	
133	366	18	0.1666	0.4552	348	
142	304	14	0.1647	0.5418	290	
155	198	13	0.1049	0.5298	185	M2/111 0.6799mg
218	144	7	0.0711	0.4938	137	
226	100	2	0.0569	0.5690	98	
227	106	8	0.0533	0.5028	98	
228	121	4	0.0653	0.5397	117	
252	34	2	0.0161	0.4735	32	
284	75	8	0.0266	0.3547	67	
296	96	2	0.0516	0.5833	94	
347	53	2	0.0287	0.5415	51	
352	89	1	0.0542	0.6090	88	
378	62	0	0.0323	0.5210	62	
532	109	11	0.0391	0.3587	98	

127	415	24	0.1960	0.4723	391	
134	348	37	0.1463	0.4204	311	
135	327	32	0.1533	0.4688	295	
136	308	28	0.1263	0.4101	280	
142	322	13	0.1604	0.4981	309	
143	316	25	0.1549	0.4902	291	M2/127 0.7270mg
150	289	3	0.1176	0.4069	286	
228	106	8	0.0433	0.4085	98	
234	135	3	0.0689	0.5104	132	
240	86	3	0.0368	0.4279	83	
252	101	2	0.0467	0.4624	99	
253	99	5	0.0440	0.4444	94	
254	92	6	0.0430	0.4674	86	
305	67	0	0.0367	0.5478	67	

467	126	20	0.0560	0.4444	106	
468	124	17	0.0505	0.4073	107	M3/30 0.8209mg
475	118	20	0.0343	0.2907	98	
480	100	35	0.0258	0.3969	65	

434	127	13	0.0272	0.2142	114	M3/116 1.0033mg
441	116	32	0.0204	0.1759	84	

448	158	0	0.0122	0.0772	158	M3/138 1.0361mg
451	165	7	0.0365	0.2212	158	

377	251	9	0.1939	0.7725	242	
378	349	10	0.2658	0.7616	339	
379	231	5	0.1379	0.5970	226	
380	239	6	0.1330	0.5565	233	M5/50 0.8236mg
381	236	2	0.1231	0.5216	234	
382	226	4	0.1066	0.4717	222	
383	140	6	0.0548	0.3914	134	
390	227	3	0.1359	0.5987	224	
395	195	0	0.0336	0.1723	195	
377	221	6	0.2130	0.9638	215	
378	177	1	0.1450	0.8192	176	
390	199	2	0.1694	0.8513	197	
381	214	1	0.1772	0.8280	213	
382	248	5	0.1836	0.7403	243	M5/67 0.9150mg
384	224	6	0.1787	0.7978	218	
385	269	2	0.1617	0.6011	267	
390	233	1	0.1707	0.7326	232	
394	238	2	0.2144	0.9008	236	
395	241	1	0.1816	0.7535	240	
376	249	8	0.1761	0.7072	241	
377	206	7	0.1413	0.6859	199	
380	218	6	0.1386	0.6358	212	
381	191	1	0.0846	0.4429	190	
382	180	3	0.1224	0.6800	177	M5/93 0.9617mg
383	218	4	0.1267	0.5812	214	
384	189	2	0.0539	0.2852	187	
385	196	0	0.0737	0.3760	196	
390	226	1	0.1060	0.4690	225	
390	194	14	0.0909	0.4686	180	
401	151	13	0.0658	0.4358	138	S1/58 0.6639mg
402	190	16	0.0803	0.4226	174	
404	95	15	0.0159	0.1674	80	
405	139	11	0.0293	0.2108	128	
380	200	17	0.1042	0.5210	183	S1/72 0.7662mg
382	154	16	0.0534	0.3468	138	
388	200	17	0.0335	0.1675	183	S1/88 0.7971mg
390	142	0	0.0097	0.0683	142	
390	192	20	0.0995	0.5182	172	
391	150	8	0.0732	0.4880	142	
392	157	21	0.0639	0.4070	136	S1/134 0.8976mg
394	467	22	0.0906	0.5425	445	
396	133	8	0.0413	0.3105	125	
398	134	17	0.0540	0.4030	117	
380	257	40	0.1228	0.4778	217	
381	230	40	0.1029	0.4474	190	
382	158	28	0.0435	0.2755	130	
390	131	34	0.0243	0.1855	97	
391	181	40	0.0825	0.4558	141	
392	203	26	0.0949	0.4675	177	S1/199 0.9758mg
393	155	25	0.0405	0.2613	130	
394	150	10	0.0335	0.2233	140	
395	173	26	0.0712	0.4162	147	
396	164	22	0.0550	0.3354	142	
400	135	7	0.0624	0.4622	128	
401	195	34	0.0478	0.2451	161	

376	527	57	0.3185	0.6045	470	
380	163	8	0.0876	0.5374	155	
381	170	15	0.0836	0.4918	155	
382	136	13	0.0443	0.3257	123	
383	137	10	0.0612	0.4467	127	S2/94 0.7749mg
384	153	8	0.0826	0.5399	145	
385	174	6	0.0752	0.4322	168	
389	181	9	0.0940	0.5193	172	
390	149	7	0.0692	0.4644	142	
391	164	5	0.0732	0.4463	159	
369	276	9	0.1890	0.6848	267	
375	172	17	0.0877	0.5099	155	
378	177	4	0.1027	0.5802	173	
382	170	11	0.0994	0.5847	159	S2/122 0.9027mg
383	170	12	0.0983	0.5782	158	
384	485	11	0.1064	0.5751	474	
385	191	11	0.1128	0.5906	180	
390	196	2	0.1020	0.5204	194	
394	194	4	0.1105	0.5995	190	
380	416	39	0.1468	0.3529	377	
383	122	0	0.0446	0.3656	122	
390	88	7	0.0399	0.4535	81	
391	102	4	0.0507	0.4971	98	
392	154	6	0.0667	0.4331	148	S2/160 1.0406mg
393	99	14	0.0275	0.2778	85	
394	101	7	0.0351	0.3475	94	
395	117	47	0.0311	0.2658	70	
396	157	15	0.0619	0.3943	142	
372	173	8	0.0942	0.5445	165	
376	130	3	0.0336	0.2585	127	
377	124	5	0.0627	0.5056	119	
378	118	5	0.0657	0.5568	113	
380	168	6	0.1020	0.6071	162	
381	122	5	0.0582	0.4770	117	
382	127	5	0.0707	0.5567	122	S2/181 1.1194mg
383	110	7	0.0597	0.5427	103	
384	134	1	0.0798	0.5955	133	
385	131	3	0.0696	0.5313	128	
386	120	5	0.0595	0.4958	115	
387	139	6	0.0626	0.4504	133	
390	176	4	0.0721	0.4097	172	
391	153	11	0.0530	0.3464	142	
392	148	10	0.0416	0.2811	138	
349	132	1	0.0836	0.6318	131	
373	145	4	0.0208	0.1434	141	S2/211 1.3116mg
381	155	0	0.0590	0.3806	155	
390	132	0	0.0212	0.1606	132	
395	300	8	0.1088	0.3627	292	S3/55 0.7417mg

382	157	1	0.1048	0.6675	156	
390	261	6	0.0630	0.2414	255	
391	111	2	0.0426	0.3838	109	
394	121	5	0.0472	0.3901	116	
395	104	2	0.0579	0.5567	102	
396	94	4	0.0177	0.1883	90	S3/134 0.9014mg
398	317	11	0.1431	0.4514	306	
399	137	2	0.0388	0.2932	135	
400	123	7	0.0097	0.0789	116	
401	115	5	0.0248	0.2157	110	
402	122	7	0.0090	0.0738	115	
403	81	7	0.0181	0.2235	74	
464	95	3	0.0587	0.6179	92	
382	142	7	0.0725	0.5106	135	
390	138	5	0.0947	0.6862	133	
391	113	6	0.0831	0.7354	107	
392	125	2	0.0778	0.6224	123	
393	102	5	0.0584	0.5725	97	S3/137 0·9038 mg
394	118	2	0.0366	0.3102	116	
395	105	4	0.0463	0.4410	101	
396	221	7	0.0909	0.4113	214	
398	105	1	0.0252	0.2400	104	
390	138	4	0.1012	0.7333	134	
394	135	3	0.1057	0.7830	132	S3/153 0.9209mg
401	93	0	0.0492	0.5290	93	
395	87	4	0.0696	0.8000	83	
396	132	14	0.0882	0.6682	118	
398	100	2	0.0472	0.4720	98	
399	168	9	0.1114	0.6631	159	S3/191 0.9732mg
400	131	4	0.0879	0.6710	127	
403	148	5	0.1110	0.7500	143	
404	127	7	0.0878	0.6913	120	
405	80	2	0.0607	0.7588	78	
376	211	4	0.1428	0.6768	207	
390	165	4	0.1124	0.6812	161	
394	360	14	0.2029	0.5636	346	S3/211 1.0250mg
398	177	5	0.0962	0.5435	172	
399	178	3	0.1067	0.5994	175	
380	161	1	0.1015	0.7000	160	
381	145	0	0.1499	0.9311	145	S4/90 0.7757mg
390	171	3	0.0921	0.5386	168	
391	126	7	0.0561	0.4452	119	
377	304	36	0.1442	0.4743	268	
381	166	7	0.0575	0.3464	159	S4/108 0.8352mg
382	127	8	0.0432	0.3638	119	
380	119	11	0.0668	0.5613	108	
381	201	6	0.1338	0.6657	195	S5/61 0.6027mg
382	157	11	0.0459	0.2924	146	
380	104	7	0.0427	0.4106	97	
381	122	8	0.0655	0.5369	114	
382	600	75	0.2536	0.4227	525	
383	153	16	0.0966	0.6314	137	S5/81 0.6467mg
390	130	9	0.0497	0.3823	121	
398	125	9	0.0430	0.3440	116	

377	386	5	0.1841	0.4769	381		
380	143	5	0.0455	0.3182	138		
381	147	8	0.0430	0.2925	139		
383	170	22	0.0544	0.3200	148	S5/103	0.6794mg
390	162	12	0.0494	0.3049	150		
395	124	7	0.0525	0.4234	117		
380	168	4	0.1018	0.6060	164		
381	579	32	0.3040	0.5250	547		
384	161	6	0.1056	0.6559	155	S5/140	0.7660mg
390	146	7	0.0659	0.4514	139		
437	99	2	0.0858	0.8667	97		
377	216	41	0.0970	0.4491	175		
390	146	11	0.0621	0.4253	135		
391	158	7	0.0473	0.2994	151	S5/214	0.9488mg
395	110	6	0.0455	0.4136	104		
397	149	8	0.0659	0.4423	141		
434	97	4	0.0689	0.7103	93		

Appendix V a Field Experiment: Flowers produced over 2 year period.

where flowered = number of flowers; clone 1= W1, clone 2=W3, clone 3=W5, clone 4=M1 and clone 5=M2. Class1=lightest achene weight class to class 4= heaviest weight class.

flowered	clone	class	block	year
3	1	1	1	1
3	1	1	2	1
6	1	1	3	1
5	1	1	4	1
6	1	2	1	1
8	1	2	2	1
7	1	2	3	1
6	1	2	4	1
8	1	3	1	1
8	1	3	2	1
5	1	3	3	1
7	1	3	4	1
5	1	4	1	1
6	1	4	2	1
7	1	4	3	1
8	1	4	4	1
2	1	1	1	2
2	1	1	2	2
3	1	1	3	2
5	1	1	4	2
2	1	2	1	2
4	1	2	2	2
4	1	2	3	2
6	1	2	4	2
4	1	3	1	2
0	1	3	2	2
2	1	3	3	2
8	1	3	4	2
5	1	4	1	2
4	1	4	2	2
6	1	4	3	2
8	1	4	4	2
4	2	1	1	1
5	2	1	2	1
4	2	1	3	1
3	2	1	4	1
5	2	2	1	1
2	2	2	2	1
4	2	2	3	1
8	2	2	4	1
4	2	3	1	1
5	2	3	2	1
6	2	3	3	1
5	2	3	4	1
5	2	4	1	1
5	2	4	2	1
5	2	4	3	1
4	2	4	4	1
1	2	1	1	2
2	2	1	2	2
3	2	1	3	2
5	2	1	4	2
2	2	2	1	2
4	2	2	2	2
3	2	2	3	2
7	2	2	4	2
3	2	3	1	2
4	2	3	2	2
2	2	3	3	2
7	2	3	4	2
2	2	4	1	2
5	2	4	2	2
3	2	4	3	2
5	2	4	4	2
4	3	1	1	1
5	3	1	2	1
5	3	1	3	1
5	3	1	4	1
6	3	2	1	1
4	3	2	2	1
4	3	2	3	1
2	3	2	4	1
2	3	3	1	1
6	5	3	3	2
5	5	3	4	2
2	5	4	1	2
6	5	4	2	2
5	5	4	3	2
8	5	4	4	2

flowered	clone	class	block	year
6	3	3	2	1
8	3	3	3	1
4	3	3	4	1
6	3	4	1	1
6	3	4	2	1
5	3	4	3	1
7	3	4	4	1
4	3	1	1	2
6	3	1	2	2
4	3	1	3	2
5	3	1	4	2
3	3	2	1	2
5	3	2	2	2
5	3	2	3	2
7	3	2	4	2
3	3	3	1	2
4	3	3	2	2
2	3	3	3	2
5	3	3	4	2
1	3	4	1	2
3	3	4	2	2
3	3	4	3	2
7	3	4	4	2
1	4	1	1	1
4	4	1	2	1
2	4	1	3	1
4	4	1	4	1
3	4	2	1	1
5	4	2	2	1
4	4	2	3	1
6	4	2	4	1
3	4	3	1	1
0	4	3	2	1
1	4	3	3	1
2	4	3	4	1
2	4	4	1	1
1	4	4	2	1
3	4	4	3	1
4	4	4	4	1
2	4	1	1	2
0	4	1	2	2
2	4	1	3	2
5	4	1	4	2
2	4	2	1	2
5	4	2	2	2
3	4	2	3	2
7	4	2	4	2
3	4	3	1	2
4	4	3	2	2
4	4	3	3	2
4	4	3	4	2
1	4	4	1	2
3	4	4	2	2
6	4	4	3	2
5	4	4	4	2
5	5	1	1	1
5	5	1	2	1
6	5	1	3	1
4	5	1	4	1
5	5	2	1	1
7	5	2	2	1
5	5	2	3	1
6	5	2	4	1
3	5	3	1	1
4	5	3	2	1
4	5	3	3	1
6	5	3	4	1
7	5	4	1	1
4	5	4	2	1
7	5	4	3	1
8	5	4	4	1
2	5	1	1	2
4	5	1	2	2
5	5	1	3	2
5	5	1	4	2
2	5	2	1	2
4	5	2	2	2
4	5	2	3	2
5	5	2	4	2
2	5	3	1	2
2	5	3	2	2

Appendix V b   Clone identification as in previous appendix. Diameter in cm.

Rosette diameter for all plants in field experiment

block	clone	class	1diam	2diam	3diam
1	1	3	7.0	24.0	16.8
1	3	1	6.7	12.7	13.5
1	4	3	7.6	25.5	19.4
1	4	2	10.3	16.2	7.0
1	5	3	9.0	14.8	2.9
1	3	2	6.9	21.2	12.1
1	1	4	9.0	27.4	18.3
1	2	1	7.4	9.4	12.7
1	2	2	9.0	22.7	14.9
1	3	3	10.0	11.4	*
1	4	4	8.0	21.5	15.0
1	5	2	6.6	13.8	*
1	2	3	11.2	23.5	19.6
1	4	1	8.9	17.4	18.0
1	5	2	4.7	25.1	20.8
1	2	3	11.2	21.8	19.1
1	3	3	7.7	18.6	16.1
1	4	1	9.0	19.8	*
1	1	1	9.8	14.4	16.4
1	3	1	10.5	17.4	14.9
1	1	1	10.8	16.3	14.5
1	3	4	11.0	23.8	17.3
1	3	3	11.5	19.3	14.4
1	3	1	5.7	*	*
1	4	1	8.6	9.8	*
1	4	2	7.9	21.2	*
1	3	2	9.9	18.2	3.2
1	2	2	10.4	18.2	13.6
1	1	2	9.8	27.6	23.7
1	2	3	11.6	15.7	18.7
1	5	4	13.7	16.4	*
1	1	2	18.3	17.1	*
1	3	1	12.2	21.5	14.8
1	2	3	5.3	*	*
1	5	4	10.2	17.8	13.9
1	3	3	3.5	11.5	8.2
1	3	3	10.2	27.4	18.6
1	1	2	6.8	20.8	15.8
1	4	2	10.8	26.2	12.7
1	2	2	10.5	*	7.1
1	5	3	9.9	8.5	*
1	1	1	7.4	22.9	*
1	3	1	10.4	16.2	*
1	5	4	11.2	16.3	*
1	4	4	11.1	13.4	4.6
1	5	2	3.7	*	*
1	5	1	7.5	16.2	*
1	1	3	10.3	22.5	15.0
1	4	4	8.6	19.0	*
1	5	3	10.9	19.0	12.2
1	1	4	9.3	19.0	*
1	4	4	10.1	15.3	11.4
1	1	3	8.2	16.5	*
1	4	2	11.7	14.7	12.8
1	3	2	15.0	17.5	17.6
1	5	1	9.3	21.2	14.0
1	1	4	10.4	28.0	19.6
1	3	4	10.4	5.4	8.3
1	2	2	7.9	*	*
1	5	3	10.7	22.5	*

block	clone	class	1diam	2diam	3diam
1	5	4	6.9	*	*
1	2	2	14.4	24.6	17.4
1	4	1	9.3	26.1	14.7
1	2	4	9.5	12.7	*
1	5	1	10.3	19.7	13.4
1	2	1	8.1	13.6	*
1	2	4	12.2	7.4	*
1	2	1	7.7	*	*
1	5	2	8.3	15.1	*
1	1	4	11.7	17.2	11.6
1	2	4	10.1	25.7	15.4
1	3	2	11.0	27.0	8.7
1	5	2	13.4	21.1	9.7
1	5	2	11.1	15.3	12.2
1	1	3	9.3	16.9	*
1	1	4	10.7	12.5	11.4
1	4	2	11.4	18.8	11.5
1	5	1	13.9	17.5	11.2
1	2	1	7.3	18.9	*
1	5	2	10.1	16.0	*
1	3	2	8.9	*	5.9
1	1	2	7.8	17.9	*
1	1	2	7.3	15.9	5.8
1	3	2	14.0	33.1	14.0
1	4	3	9.3	29.5	*
1	3	1	5.5	*	*
1	4	3	9.5	14.3	17.0
1	2	4	10.0	18.7	*
1	1	3	8.0	20.0	13.9
1	5	1	7.7	20.0	15.0
1	4	3	8.6	16.8	18.3
1	2	1	4.6	*	*
1	4	4	16.8	29.4	19.2
1	2	3	13.5	16.1	11.2
1	1	1	6.5	7.8	7.9
1	1	4	12.2	11.8	7.9
1	5	2	10.8	19.2	9.1
1	2	3	8.4	14.7	10.4
1	2	2	8.3	*	*
1	1	1	6.8	*	*
1	5	3	5.9	*	*
1	3	1	8.2	*	*
1	1	1	5.2	*	*
1	5	4	9.3	1.6	*
1	1	2	9.1	1.7	*
1	2	4	8.4	28.0	17.0
1	5	1	11.1	11.3	*
1	2	1	10.2	13.6	7.1
1	1	1	6.2	*	*
1	5	1	5.3	*	*
1	4	3	10.4	18.4	12.7
1	2	4	9.2	17.7	3.8
1	4	1	11.7	18.4	*
1	5	1	10.4	19.8	11.8
1	4	2	9.3	20.4	21.7
1	5	2	12.4	*	*
1	4	4	8.6	23.3	12.6
1	5	4	10.0	15.1	*
1	2	3	8.6	*	*
1	4	3	9.5	20.5	9.6

block	clone	class	1diam	2diam	3diam
1	3	4	9.9	12.2	3.3
1	4	1	8.1	15.0	*
1	3	1	8.7	14.5	*
1	1	3	9.8	*	*
1	3	4	7.6	16.2	7.1
1	2	1	10.7	18.4	*
1	1	1	10.5	*	*
1	3	3	9.5	20.2	*
1	3	4	11.4	21.0	17.2
1	2	4	9.9	15.4	*
1	3	3	8.1	18.5	*
1	1	3	10.2	2.2	3.5
1	5	3	10.8	5.7	11.7
1	3	1	13.4	4.9	7.4
1	3	2	10.5	29.3	2.9
1	2	3	13.8	28.7	11.0
1	3	2	10.4	20.9	13.6
1	3	1	12.3	16.0	1.7
1	2	4	12.3	24.6	3.2
1	4	3	7.7	23.1	15.6
1	1	4	7.6	13.5	11.9
1	5	4	8.0	18.4	9.8
1	2	2	9.1	18.3	10.9
1	4	3	10.2	28.2	7.6
1	1	1	12.0	23.8	13.1
1	3	4	9.4	15.5	*
1	5	4	10.9	18.6	14.3
1	2	2	7.7	12.4	*
1	3	4	10.2	15.4	*
1	4	2	11.1	21.1	4.0
1	5	1	3.4	7.1	*
1	2	1	9.0	12.7	*
1	1	3	6.4	18.5	20.5
1	1	4	10.1	22.8	4.9
1	3	1	11.1	*	*
1	1	2	9.4	20.2	*
1	4	4	5.4	*	*
2	5	2	10.5	*	*
2	3	3	8.6	16.2	10.0
2	3	2	12.8	22.4	15.3
2	5	4	11.6	14.4	*
2	4	3	8.0	16.1	20.4
2	1	1	9.9	*	8.0
2	5	1	9.6	19.0	11.5
2	4	2	9.5	14.0	20.5
2	2	4	8.1	17.4	16.1
2	3	1	3.1	19.3	13.7
2	5	3	6.9	17.3	10.4
2	4	3	10.7	17.9	14.5
2	5	2	12.7	17.4	23.4
2	5	4	10.1	10.5	17.1
2	5	3	8.8	19.9	*
2	5	2	8.1	13.6	11.7
2	4	4	10.7	22.0	16.9
2	4	4	9.0	17.9	20.5
2	5	4	8.1	15.6	15.4
2	3	1	11.6	16.8	16.8
2	2	3	10.7	18.3	12.2
2	4	4	9.7	18.4	12.0
2	1	2	7.4	13.5	19.3

block	clone	class	1diam	2diam	3diam
2	2	2	8.6	18.2	17.0
2	3	2	7.6	11.1	13.3
2	5	2	11.5	16.9	*
2	1	1	7.3	11.2	12.9
2	1	3	9.8	17.1	14.3
2	1	4	9.0	2.9	*
2	2	1	12.3	20.7	16.2
2	3	4	8.4	19.6	17.8
2	2	2	13.6	25.8	14.9
2	2	1	8.1	*	*
2	1	3	8.1	20.5	*
2	2	4	13.1	17.3	16.0
2	1	1	13.6	18.8	16.6
2	3	2	12.8	19.5	17.0
2	4	3	8.7	24.8	27.3
2	5	1	11.3	21.2	16.4
2	1	2	12.3	22.8	11.2
2	1	2	11.6	22.7	10.1
2	2	2	6.5	2.6	3.9
2	5	1	11.3	20.7	18.4
2	5	4	10.8	14.4	16.7
2	5	1	12.5	17.7	18.0
2	1	3	9.7	22.3	2.6
2	1	2	12.2	19.8	*
2	2	1	6.2	5.6	9.8
2	4	1	10.6	*	*
2	3	3	9.5	17.8	*
2	4	2	8.9	16.5	13.3
2	2	2	9.0	19.0	18.7
2	1	2	6.3	19.3	13.3
2	4	1	8.6	25.0	20.4
2	4	3	8.8	25.3	18.6
2	1	3	9.0	*	5.8
2	5	4	9.3	4.9	16.6
2	2	2	8.7	16.9	*
2	4	1	11.5	15.8	25.0
2	4	2	11.0	18.4	16.0
2	3	4	5.5	15.3	*
2	2	4	7.4	*	*
2	4	1	8.3	23.0	6.2
2	1	4	12.7	23.1	15.3
2	2	1	9.9	22.5	*
2	1	1	7.9	*	*
2	5	3	7.5	*	2.9
2	1	3	10.8	3.3	*
2	5	3	12.5	18.7	15.2
2	3	2	12.1	13.6	11.2
2	1	3	11.5	23.3	*
2	2	3	11.6	27.4	19.1
2	2	3	12.6	15.0	*
2	3	4	9.1	18.7	14.5
2	2	1	14.4	13.0	14.4
2	3	1	10.4	14.1	10.6
2	2	3	8.8	18.7	18.5
2	2	2	5.9	10.0	2.1
2	3	2	9.6	19.3	9.1
2	3	3	7.8	17.0	9.0
2	1	3	10.3	18.6	*
2	3	1	10.9	14.8	14.7
2	2	2	11.0	17.8	17.4

block	clone	class	1diam	2diam	3diam
2	2	1	8.4	14.8	8.7
2	2	1	8.8	*	*
2	1	4	5.4	16.4	14.2
2	5	4	13.4	19.9	*
2	3	2	6.9	*	5.0
2	2	1	9.1	12.8	9.8
2	1	2	10.6	14.8	8.5
2	1	2	14.0	22.0	20.9
2	4	1	11.6	6.6	*
2	3	3	15.5	14.3	16.8
2	3	3	8.4	11.9	6.8
2	4	2	6.6	8.3	*
2	5	1	11.6	15.3	*
2	2	3	8.1	*	*
2	3	2	15.6	20.3	7.0
2	4	3	11.0	13.7	10.6
2	5	2	9.3	10.8	*
2	5	2	11.2	13.3	*
2	5	1	7.6	14.5	14.9
2	5	3	4.9	*	*
2	4	4	7.2	*	*
2	4	4	11.0	13.1	*
2	5	3	9.9	10.8	1.3
2	3	1	12.7	*	*
2	3	4	14.8	19.1	1.9
2	4	4	4.9	12.1	*
2	4	1	9.4	12.6	13.2
2	4	3	7.4	15.6	12.2
2	1	4	19.1	22.6	17.8
2	3	4	14.8	13.4	*
2	1	3	9.5	*	*
2	4	4	10.2	14.0	*
2	2	3	6.1	*	*
2	4	3	5.2	14.0	*
2	1	4	7.3	14.4	19.6
2	1	2	10.3	18.0	22.2
2	1	3	7.7	18.1	*
2	3	3	20.0	20.8	15.8
2	5	2	11.0	13.3	*
2	5	4	9.2	20.7	13.4
2	5	4	9.7	15.9	13.7
2	3	4	11.1	15.0	10.0
2	5	1	8.8	12.9	*
2	2	4	10.8	18.4	9.4
2	3	2	11.8	20.8	10.8
2	4	1	6.6	*	*
2	3	1	11.6	*	*
2	1	1	9.8	*	*
2	3	1	10.5	15.4	*
2	3	4	15.3	*	*
2	1	4	8.9	*	*
2	3	4	9.8	11.7	8.9
2	5	1	6.3	8.6	*
2	3	3	11.1	15.4	*
2	1	4	9.2	*	*
2	3	1	12.4	16.8	13.5
2	5	3	6.6	15.9	9.4
2	5	2	8.1	*	4.8
2	4	2	10.1	14.7	14.1
2	4	4	9.5	15.7	17.7

block	clone	class	1diam	2diam	3diam
2	2	4	11.1	13.1	3.7
2	2	3	11.7	13.8	14.8
2	2	1	11.0	19.5	18.0
2	4	1	7.7	8.3	1.3
2	1	1	12.7	17.6	*
2	4	1	11.8	14.0	7.7
2	3	3	14.3	9.5	13.9
2	2	4	11.4	15.1	7.2
2	2	2	7.0	12.7	1.9
2	1	1	12.2	20.4	13.5
2	2	4	11.2	18.3	16.0
3	2	4	7.1	22.3	15.1
3	5	4	6.6	15.4	*
3	1	1	11.2	21.2	9.5
3	2	1	8.6	2.4	7.7
3	1	1	10.8	30.1	14.1
3	4	2	12.0	*	*
3	2	3	8.5	15.4	10.1
3	4	2	11.2	15.7	22.2
3	5	2	13.1	20.6	13.5
3	5	2	13.3	24.6	13.9
3	4	1	10.8	29.4	15.5
3	1	2	12.0	31.9	17.9
3	5	3	11.1	32.6	22.7
3	2	1	9.5	*	4.5
3	5	4	12.2	15.0	*
3	4	1	7.5	14.5	9.3
3	4	2	12.0	19.9	9.6
3	3	2	15.1	14.7	17.3
3	1	4	9.3	25.5	18.6
3	3	3	13.3	22.0	23.8
3	5	4	13.0	30.3	25.4
3	4	1	10.5	18.7	20.2
3	1	1	8.1	10.6	8.5
3	2	3	14.2	21.4	18.2
3	3	1	9.7	15.1	13.3
3	3	4	13.0	10.8	3.9
3	5	4	14.3	25.7	22.8
3	4	1	11.6	22.1	22.7
3	5	3	9.4	9.5	*
3	2	1	10.9	24.0	21.4
3	1	4	16.9	25.4	20.6
3	4	3	7.6	12.6	13.6
3	2	1	10.2	13.7	7.9
3	1	2	5.9	20.0	*
3	1	4	8.9	34.4	41.6
3	1	4	11.1	37.7	7.8
3	5	3	10.8	26.0	15.6
3	4	3	9.0	19.0	18.2
3	4	4	11.8	19.9	17.1
3	5	4	9.4	21.1	13.5
3	2	2	6.1	13.3	2.7
3	4	2	11.2	14.1	*
3	4	1	7.1	16.4	13.5
3	3	4	10.8	30.0	17.3
3	3	2	10.8	18.6	14.8
3	3	3	12.0	20.4	17.4
3	5	1	6.9	13.5	10.0
3	1	4	8.8	17.9	*
3	3	3	9.9	1.5	1.8

block	clone	class	1diam	2diam	3diam
3	1	3	10.4	23.2	17.7
3	5	2	10.7	28.0	18.0
3	4	4	8.9	27.8	19.4
3	2	2	7.9	21.5	8.7
3	4	2	8.5	20.6	17.3
3	1	3	7.5	24.6	14.1
3	5	1	8.4	*	1.5
3	2	4	7.6	*	*
3	2	3	11.4	29.1	21.5
3	5	2	10.7	19.5	14.4
3	5	3	9.2	19.2	12.6
3	1	1	14.2	23.3	9.5
3	3	2	2.6	3.5	3.6
3	1	3	9.4	17.5	17.8
3	3	4	11.7	26.2	17.4
3	4	3	9.8	23.3	11.7
3	3	1	6.9	24.0	20.0
3	5	1	15.2	13.9	8.7
3	5	1	11.4	11.6	14.4
3	4	1	9.1	8.9	4.2
3	4	2	9.7	*	*
3	5	3	9.8	28.4	17.8
3	2	2	7.6	20.9	4.1
3	4	3	10.4	20.2	25.4
3	1	4	7.8	20.7	15.7
3	1	3	8.4	15.1	2.9
3	1	2	7.1	20.2	16.2
3	3	4	10.4	14.1	15.6
3	1	1	8.4	14.7	*
3	5	4	10.9	24.2	28.1
3	1	3	7.0	2.9	*
3	2	2	8.7	15.7	15.6
3	3	2	9.9	11.7	7.5
3	2	4	9.9	12.5	7.4
3	2	2	8.5	13.3	*
3	5	3	11.7	16.7	17.9
3	2	3	8.6	25.7	*
3	3	4	14.5	19.9	14.7
3	2	4	12.3	15.2	9.4
3	1	2	10.9	19.8	*
3	3	4	10.0	11.0	12.1
3	2	1	5.7	8.2	8.0
3	1	1	10.6	15.4	*
3	4	2	12.1	20.0	8.4
3	2	1	9.5	22.0	19.7
3	5	3	12.7	24.7	16.7
3	1	3	7.6	14.4	13.5
3	3	1	7.4	4.8	5.8
3	4	4	6.4	14.4	7.9
3	5	3	10.3	8.8	9.8
3	5	2	10.3	13.1	*
3	1	2	7.7	20.9	*
3	5	2	9.7	21.7	22.9
3	4	4	6.0	18.4	18.4
3	5	1	7.8	7.2	*
3	2	3	8.8	4.8	6.3
3	4	1	4.6	*	7.2
3	3	2	5.5	2.4	7.6
3	3	3	12.8	18.8	7.4
3	3	1	9.0	16.9	*

block	clone	class	1diam	2diam	3diam
3	3	1	10.0	33.4	21.8
3	4	2	8.7	20.8	6.7
3	5	2	8.5	12.4	12.4
3	4	3	9.1	11.5	13.2
3	2	2	7.2	9.8	9.4
3	3	1	6.1	11.9	7.0
3	2	1	8.2	12.2	11.2
3	2	3	10.0	22.7	16.3
3	2	2	8.4	16.4	10.2
3	3	2	13.2	15.1	*
3	1	2	10.1	*	*
3	3	4	8.2	*	6.8
3	2	4	7.7	12.2	14.2
3	3	4	7.6	16.9	11.6
3	1	3	10.6	10.8	4.5
3	5	1	10.6	20.6	16.0
3	3	3	11.7	5.0	10.3
3	5	1	9.9	*	2.0
3	3	2	11.5	13.4	13.0
3	2	4	7.6	6.9	*
3	3	1	8.6	10.6	12.1
3	5	4	7.6	7.9	13.1
3	2	2	8.1	14.3	*
3	4	4	9.8	17.5	8.6
3	3	2	16.4	18.2	16.3
3	2	3	9.4	8.6	11.9
3	4	2	5.0	8.5	14.4
3	3	3	12.1	11.5	11.8
3	1	4	9.3	16.1	*
3	5	2	8.6	*	10.1
3	4	4	9.1	17.6	19.0
3	1	4	9.9	29.2	17.6
3	5	1	10.8	21.9	10.7
3	3	1	14.2	17.3	*
3	3	3	9.3	*	*
3	4	4	6.3	14.5	*
3	1	2	5.9	*	1.6
3	4	3	7.5	14.3	9.5
3	1	2	10.5	15.1	18.6
3	2	4	8.8	17.2	*
3	2	4	11.9	9.7	*
3	1	1	11.1	*	9.7
3	2	1	10.2	*	4.8
3	1	3	9.1	14.4	*
3	5	2	7.4	9.8	9.3
3	3	3	8.3	12.4	12.0
4	5	1	9.9	7.4	9.8
4	1	2	10.5	17.3	*
4	5	4	13.4	14.9	13.0
4	3	3	10.8	4.6	7.9
4	4	2	9.7	12.1	17.9
4	4	1	13.8	18.9	14.9
4	4	3	6.3	19.4	17.5
4	3	2	9.6	18.8	21.3
4	2	2	9.4	11.1	12.2
4	2	4	9.2	8.9	9.6
4	1	2	11.6	16.5	16.5
4	1	1	7.2	11.3	12.3
4	1	4	10.6	12.9	12.2
4	1	3	13.6	16.2	19.2

block	clone	class	1diam	2diam	3diam
4	4	2	13.6	15.9	10.0
4	4	3	12.1	12.5	6.1
4	1	2	10.3	28.4	19.5
4	1	4	8.1	20.0	9.9
4	1	1	10.1	21.1	19.2
4	4	3	8.7	14.7	18.6
4	4	1	11.5	13.5	20.1
4	2	3	12.4	12.2	107.0
4	5	2	11.2	10.6	9.9
4	2	4	11.8	19.9	16.9
4	5	4	9.9	21.3	15.4
4	3	3	10.0	13.9	*
4	4	4	12.1	14.2	13.1
4	2	3	10.2	12.1	5.5
4	2	1	9.2	*	15.3
4	1	4	10.5	16.4	17.6
4	2	4	6.2	*	8.3
4	3	4	14.3	13.0	15.2
4	2	4	7.8	14.9	*
4	2	2	10.4	10.7	11.8
4	5	3	12.8	7.8	12.0
4	4	2	8.6	13.4	19.0
4	3	2	9.3	14.0	12.4
4	4	3	10.9	12.9	11.4
4	1	4	12.0	18.3	20.8
4	3	1	11.3	13.6	14.3
4	2	3	10.6	9.4	9.9
4	2	4	5.5	11.3	14.2
4	1	4	9.8	25.7	15.9
4	4	2	6.9	5.3	5.9
4	1	4	9.9	11.8	18.0
4	1	1	7.9	12.5	17.8
4	1	1	11.3	21.6	16.5
4	4	4	10.7	19.3	*
4	2	1	10.2	12.4	13.4
4	4	3	11.5	15.6	17.9
4	2	4	12.4	15.8	15.8
4	1	2	15.2	18.9	16.5
4	5	1	7.1	12.0	10.2
4	3	1	9.5	15.7	15.2
4	3	3	7.9	19.5	15.4
4	3	3	9.8	10.2	8.5
4	1	1	11.1	11.7	17.4
4	1	4	12.5	10.4	*
4	3	1	11.3	16.0	15.3
4	3	3	12.3	19.7	17.2
4	3	3	15.2	15.9	14.6
4	1	2	10.2	17.0	23.4
4	3	1	13.3	20.0	21.8
4	4	2	9.5	18.1	13.7
4	1	3	11.2	20.9	17.9
4	1	3	10.0	15.5	18.4
4	2	1	10.3	16.6	7.0
4	5	4	15.5	21.4	17.3
4	2	1	9.9	15.8	15.3
4	4	1	11.6	16.6	18.0
4	4	2	13.3	25.1	21.7
4	1	4	7.3	12.9	13.7
4	3	1	7.6	13.7	4.5
4	2	1	7.2	13.7	17.1

block	clone	class	1diam	2diam	3diam
4	4	4	11.4	15.4	16.9
4	3	1	9.3	12.4	7.0
4	5	4	10.3	20.6	11.8
4	2	2	10.5	11.9	9.6
4	2	3	11.0	17.4	16.5
4	2	3	8.6	11.1	12.3
4	4	3	11.5	13.9	16.5
4	2	2	10.4	12.4	*
4	5	1	8.9	12.3	12.8
4	5	1	10.2	13.5	*
4	1	1	11.4	20.3	18.6
4	1	2	15.2	21.8	22.2
4	3	4	14.4	15.1	16.7
4	4	4	9.1	14.7	17.6
4	3	4	9.9	19.7	19.8
4	1	3	9.6	16.7	17.1
4	5	2	13.5	18.2	19.0
4	1	3	9.3	16.1	21.5
4	2	1	4.9	10.7	13.5
4	5	3	12.5	22.4	13.7
4	5	2	11.4	20.5	16.8
4	2	2	8.4	16.0	17.9
4	1	2	13.8	25.5	*
4	5	3	10.2	24.1	13.5
4	4	4	12.8	25.3	26.0
4	5	4	12.1	19.3	17.0
4	4	3	12.7	15.2	14.9
4	5	2	12.0	7.4	*
4	2	3	13.4	18.5	18.0
4	3	2	9.1	18.3	14.6
4	3	4	12.2	24.1	18.7
4	3	1	17.0	23.6	20.4
4	3	4	11.4	16.3	*
4	4	4	10.5	20.0	*
4	2	1	11.8	15.4	8.4
4	5	4	11.9	13.5	11.3
4	3	2	9.0	14.9	14.0
4	5	2	6.4	9.8	5.4
4	2	2	11.4	19.1	*
4	2	4	12.8	12.8	11.9
4	1	4	10.1	33.2	34.3
4	2	2	11.7	11.8	14.2
4	1	1	9.9	14.2	*
4	4	1	9.3	11.8	15.4
4	3	4	10.7	20.8	12.9
4	4	1	11.2	13.7	*
4	5	3	6.9	13.1	14.7
4	4	2	12.2	32.0	25.9
4	2	1	12.1	24.6	21.7
4	5	2	8.8	16.0	20.4
4	5	3	10.0	*	*
4	5	1	14.9	14.0	15.8
4	3	1	10.5	10.7	13.7
4	1	3	8.4	*	*
4	5	2	11.6	16.3	*
4	2	2	11.2	17.3	22.2
4	5	3	11.4	23.0	12.1
4	4	1	13.1	29.8	17.0
4	1	3	9.3	15.9	9.1
4	3	4	11.3	24.3	21.5

block	clone	class	1diam	2diam	3diam
4	3	3	10.5	12.9	12.3
4	5	3	13.1	11.4	13.9
4	4	4	9.0	23.3	20.6
4	3	4	12.6	23.2	16.3
4	3	2	11.6	32.2	26.8
4	5	1	8.5	*	*
4	5	2	8.2	6.4	10.3
4	4	1	10.4	11.5	9.1
4	5	1	10.1	10.3	14.5
4	5	4	11.6	25.4	14.5
4	2	3	11.1	23.5	16.2
4	4	4	8.4	12.4	18.6
4	5	4	17.0	21.9	22.4
4	5	3	16.4	18.6	22.4
4	3	2	10.1	14.1	11.6
4	2	2	10.7	13.5	13.8
4	4	2	8.1	17.6	*
4	1	2	8.6	20.1	*
4	2	4	14.0	26.5	16.6
4	3	2	12.8	26.2	17.9
4	2	3	14.9	17.0	18.1
4	1	3	10.4	28.8	18.1

Appendix V c

Clone identifcation as in previous experiment. Root crown diameter in cr dry weight in g.

Final assessment of root crown diameter and dry weight.

block	clone	class	rcrown	dwt
1	1	3	26.0	1.10
1	3	1	26.5	0.52
1	4	4	5.5	0.02
1	5	1	14.9	0.33
1	5	4	18.7	0.96
1	3	1	11.4	0.29
1	5	3	16.7	0.41
1	2	4	18.7	0.24
1	4	2	27.7	1.12
1	1	1	15.3	0.15
1	5	1	13.0	0.26
1	3	3	16.9	1.23
1	2	3	11.6	1.21
1	2	1	2.0	0.01
1	1	4	24.2	0.56
1	4	3	15.7	0.83
1	2	3	5.4	0.02
1	2	4	34.4	3.12
1	3	4	15.5	0.31
1	3	2	23.1	1.14
1	1	3	21.4	0.35
1	2	3	24.5	1.19
1	1	2	22.4	0.87
1	3	3	19.6	0.99
1	4	2	34.2	2.58
1	3	4	6.6	0.05
1	1	4	5.4	0.02
1	2	3	21.9	0.74
1	1	2	26.1	1.30
1	2	2	21.2	1.79
1	5	1	12.6	0.45
1	4	4	23.0	3.38
1	3	3	25.8	0.58
1	5	4	18.8	0.80
1	1	4	25.7	6.84
1	2	2	15.5	0.31
1	4	3	9.2	0.06
1	1	1	4.8	0.02
1	1	4	7.5	0.11
2	2	4	17.9	0.41
2	4	4	25.7	1.74
2	3	2	6.3	0.06
2	2	2	12.9	0.29
2	1	2	18.2	1.73
2	1	3	10.2	0.41
2	2	3	14.2	0.50
2	4	2	2.0	0.04
2	3	3	3.5	0.22
2	3	1	16.5	0.52
2	4	4	19.5	2.40
2	4	1	15.1	0.33
2	1	4	19.3	1.47
2	3	4	1.3	0.01
2	1	1	7.7	0.02
2	3	2	10.3	0.24
2	5	4	15.9	0.28
2	5	4	14.4	0.44
2	3	1	9.2	0.05
2	2	1	14.6	0.42
2	5	1	12.8	0.08

block	clone	class	rcrown	dwt
2	4	3	12.6	0.47
2	1	2	12.9	0.49
2	2	4	9.0	0.19
2	4	2	5.0	0.03
2	4	1	11.4	0.30
2	5	1	12.3	0.29
2	4	1	31.9	2.60
2	2	2	14.8	0.56
2	2	3	31.5	4.53
2	1	4	13.0	0.37
2	4	3	12.2	0.41
2	5	2	13.8	0.30
2	2	3	12.0	0.38
2	1	3	8.8	0.19
2	1	1	15.1	0.52
2	5	4	6.6	0.11
2	2	2	10.5	0.25
2	4	2	8.0	0.12
2	1	3	7.8	0.11
2	3	1	16.6	0.76
2	1	1	4.8	0.04
2	5	4	12.6	0.59
2	4	4	16.0	0.80
2	3	2	8.3	0.15
2	5	1	15.9	0.28
2	1	2	24.3	0.69
2	2	3	13.9	1.19
2	2	4	8.9	0.21
2	4	3	21.4	2.05
2	4	1	20.6	1.99
2	3	3	18.4	1.81
2	5	2	7.1	0.04
2	5	4	15.6	0.28
2	4	2	20.0	1.55
2	2	2	5.7	0.10
2	3	4	15.8	0.42
2	5	1	13.7	0.39
2	4	3	20.8	2.20
2	4	1	13.1	0.27
2	3	2	13.3	1.74
2	1	4	15.3	0.61
2	5	4	14.8	1.28
2	3	1	15.1	0.78
2	2	1	19.8	1.22
3	2	4	15.7	0.70
3	5	2	18.1	1.08
3	4	2	10.1	0.53
3	3	1	16.0	0.56
3	4	3	21.2	1.54
3	5	4	9.3	0.30
3	4	1	1.8	0.01
3	3	4	10.7	0.70
3	2	1	17.5	1.52
3	1	3	9.1	0.28
3	4	4	20.6	1.32
3	3	2	17.2	1.35
3	3	4	6.9	0.08
3	2	2	19.4	0.68
3	1	3	2.1	0.02
3	1	1	5.1	0.02

block	clone	class	rcrown	dwt
3	5	3	15.5	1.40
3	2	3	14.6	0.44
3	5	1	16.8	0.98
3	4	4	8.0	0.24
3	1	4	7.3	0.02
3	2	4	16.4	0.70
3	1	4	15.9	1.96
3	1	4	22.0	4.45
3	4	2	12.5	0.78
3	1	3	14.6	0.44
3	3	4	15.1	1.58
3	5	3	19.1	4.01
3	5	4	19.3	3.80
3	2	3	18.3	1.18
3	2	1	15.4	1.45
3	5	2	12.2	1.43
3	3	1	28.8	4.03
3	1	2	6.5	0.17
3	3	3	21.8	2.63
3	5	4	24.7	3.11
3	1	4	34.3	13.52
3	4	1	15.9	3.00
3	5	2	18.0	1.82
3	2	4	4.4	0.05
3	2	2	15.3	0.78
3	3	4	17.0	0.48
3	5	3	22.0	1.43
3	1	1	9.4	0.25
3	1	1	14.7	1.16
3	5	3	20.2	1.73
3	5	4	24.4	0.60
3	4	1	24.1	2.31
3	1	4	19.4	1.62
3	3	4	23.0	2.09
3	4	4	22.5	3.06
3	2	3	17.9	1.40
3	3	1	18.5	4.98
3	4	3	19.8	3.43
3	2	2	13.4	0.61
3	2	4	16.0	1.17
3	1	3	6.3	0.11
3	3	2	20.6	1.31
3	4	2	18.3	1.05
3	2	1	7.2	0.12
3	4	1	16.3	1.94
3	5	4	16.9	1.74
3	3	2	13.7	0.77
3	5	2	17.8	3.00
3	1	4	20.1	1.24
3	2	3	11.9	0.48
3	3	4	9.0	0.46
3	1	1	15.0	0.70
3	2	1	17.1	0.88
3	4	3	18.9	1.63
3	4	2	18.1	1.71
3	5	3	10.9	0.64
3	5	1	13.1	0.96
3	1	3	5.1	0.17
3	3	2	18.4	0.65
3	3	4	21.8	1.14

block	clone	class	rcrown	dwt
3	4	4	5.1	0.04
3	4	1	9.7	0.15
3	3	1	17.1	0.44
3	1	2	22.0	1.07
3	5	2	19.9	0.55
3	4	2	21.4	1.26
3	4	1	18.5	1.10
3	2	3	20.5	1.47
3	1	4	13.6	1.24
3	4	4	16.8	0.75
3	1	3	17.4	0.56
3	1	1	12.3	0.21
3	1	2	11.6	0.31
3	2	4	10.7	0.26
3	5	3	13.3	0.41
3	3	2	10.4	0.30
3	5	4	11.6	1.03
3	3	3	13.1	0.46
4	5	1	13.9	0.22
4	2	2	15.4	0.78
4	1	2	16.7	0.66
4	5	4	18.2	0.78
4	2	4	16.7	1.14
4	4	2	4.0	0.11
4	1	4	11.5	0.33
4	3	4	7.4	0.15
4	4	3	15.8	1.24
4	1	3	18.0	0.61
4	5	2	10.2	0.39
4	3	2	13.0	0.51
4	2	4	18.4	0.56
4	1	4	16.8	0.78
4	2	2	22.1	0.99
4	1	1	8.7	0.38
4	1	3	9.1	0.30
4	4	3	13.0	0.37
4	4	4	18.2	0.85
4	5	3	10.0	0.44
4	5	4	13.8	0.64
4	4	1	12.6	0.54
4	3	4	18.0	1.78
4	5	4	9.3	0.26
4	1	2	16.9	0.62
4	1	1	11.7	0.59
4	4	4	11.9	0.56
4	5	3	15.9	1.40
4	2	4	4.0	0.01
4	4	3	14.2	0.81
4	1	4	10.5	0.15
4	1	3	10.5	0.35
4	2	1	13.4	0.33
4	2	3	22.8	2.10
4	3	4	16.7	0.68
4	5	1	19.6	1.06
4	4	3	13.9	0.87
4	2	3	9.8	0.16
4	4	2	15.5	0.56
4	1	4	12.2	0.21
4	4	4	18.6	0.40
4	5	1	21.4	1.12

block	clone	class	rcrown	dwt
4	3	4	24.9	4.41
4	2	2	16.5	1.25
4	3	2	10.5	0.15
4	5	3	11.0	0.42
4	5	4	16.8	0.88
4	4	2	16.4	0.61
4	1	4	12.7	0.38
4	4	1	13.5	1.15
4	2	1	18.0	0.66
4	3	2	20.8	0.69
4	4	2	8.9	0.29
4	1	2	20.5	0.82
4	5	4	25.0	0.95
4	1	3	14.3	1.51
4	1	2	17.2	0.29
4	3	4	17.2	0.69
4	2	2	3.8	0.03
4	5	3	15.3	0.48
4	5	2	4.5	0.03
4	4	4	16.1	1.59
4	2	3	11.9	0.44
4	2	4	14.3	0.44
4	4	1	21.4	2.18
4	2	3	13.9	0.68
4	4	3	16.7	0.70
4	1	4	11.8	0.37
4	5	1	3.7	0.07
4	2	1	15.0	0.40
4	5	4	4.8	0.09
4	1	1	4.3	0.09
4	5	2	12.0	0.41
4	3	1	14.7	1.51
4	2	4	13.4	0.75
4	4	2	14.5	1.14
4	3	4	14.2	0.29
4	4	4	15.4	1.26
4	3	2	16.2	0.78
4	4	3	8.1	0.38
4	4	2	20.1	0.59
4	2	4	7.6	0.20
4	2	3	9.6	0.54
4	1	1	24.8	1.11
4	3	1	17.2	0.46
4	1	2	10.4	0.44
4	4	1	20.7	0.97
4	1	3	20.0	0.87
4	4	4	7.7	0.26
4	3	4	7.7	0.16
4	1	4	32.4	7.31
4	2	1	15.1	0.97
4	5	3	10.7	0.25
4	3	2	22.5	2.27
4	5	4	19.7	1.27
4	2	3	19.7	2.12
4	3	2	13.9	0.35
4	2	4	19.9	0.80
4	3	4	6.0	0.20
4	1	4	14.3	0.25
4	1	1	6.7	0.13
4	3	3	14.7	0.60

block	clone	class	rcrown	dwt
4	3	1	21.0	1.13
4	4	2	12.6	0.74
4	2	3	6.7	0.12
4	1	2	20.8	1.08
4	5	4	1.6	0.06
4	2	2	20.3	0.80
4	5	2	18.6	0.64
4	4	1	20.2	0.84
4	5	3	17.2	0.53

Appendix V d **Number of leaves and ELA for subset; year 1.**

Clone identification as before. Size as before. Time is assessment number.

no. lves	ELA	clone	size	block	time
8	31	3	1	1	1
7	28	3	1	1	2
9	34	3	1	1	3
7	30	3	1	1	4
8	35	3	1	1	5
7	36	3	1	1	6
6	21	3	1	1	7
7	28	3	1	1	8
7	27	3	1	1	9
8	34	3	1	1	10
8	31	3	1	1	11
10	35	3	1	1	12
17	52	1	4	1	1
11	40	1	4	1	2
10	60	1	4	1	3
10	84	1	4	1	4
10	69	1	4	1	5
11	72	1	4	1	6
15	113	1	4	1	7
16	140	1	4	1	8
18	144	1	4	1	9
21	214	1	4	1	10
26	218	1	4	1	11
27	253	1	4	1	12
9	58	1	1	1	1
9	35	1	1	1	2
8	36	1	1	1	3
8	58	1	1	1	4
9	52	1	1	1	5
9	57	1	1	1	6
8	52	1	1	1	7
11	71	1	1	1	8
11	102	1	1	1	9
6	91	1	1	1	10
7	91	1	1	1	11
11	93	1	1	1	12
17	69	5	4	1	1
12	42	5	4	1	2
12	52	5	4	1	3
13	72	5	4	1	4
9	60	5	4	1	5
11	62	5	4	1	6
10	72	5	4	1	7
16	76	5	4	1	8
15	76	5	4	1	9
14	72	5	4	1	10
14	69	5	4	1	11
15	84	5	4	1	12
6	60	4	4	1	1
6	39	4	4	1	2
4	35	4	4	1	3
5	52	4	4	1	4
6	47	4	4	1	5
6	53	4	4	1	6
8	56	4	4	1	7
10	79	4	4	1	8
11	76	4	4	1	9
12	81	4	4	1	10
13	88	4	4	1	11
15	104	4	4	1	12

no. lves	ELA	clone	size	block	time
11	68	4	1	1	1
11	47	4	1	1	2
9	96	4	1	1	3
8	79	4	1	1	4
6	89	4	1	1	5
7	124	4	1	1	6
11	127	4	1	1	7
13	216	4	1	1	8
15	241	4	1	1	9
13	212	4	1	1	10
17	217	4	1	1	11
21	204	4	1	1	12
13	45	2	4	1	1
8	29	2	4	1	2
8	35	2	4	1	3
7	35	2	4	1	4
6	32	2	4	1	5
3	20	2	4	1	6
5	37	2	4	1	7
10	31	2	4	1	8
9	27	2	4	1	9
9	21	2	4	1	10
8	23	2	4	1	11
10	23	2	4	1	12
6	34	2	1	1	1
5	22	2	1	1	2
6	34	2	1	1	3
4	30	2	1	1	4
3	28	2	1	1	5
4	29	2	1	1	6
4	19	2	1	1	7
6	49	2	1	1	8
6	46	2	1	1	9
4	29	2	1	1	10
2	11	2	1	1	11
*	*	2	1	1	12
8	30	5	1	1	1
7	27	5	1	1	2
6	26	5	1	1	3
6	38	5	1	1	4
5	35	5	1	1	5
7	42	5	1	1	6
10	49	5	1	1	7
10	97	5	1	1	8
12	116	5	1	1	9
11	107	5	1	1	10
14	139	5	1	1	11
17	140	5	1	1	12
13	37	4	4	1	1
8	45	4	4	1	2
8	64	4	4	1	3
8	100	4	4	1	4
9	102	4	4	1	5
11	171	4	4	1	6
14	140	4	4	1	7
16	267	4	4	1	8
17	270	4	4	1	9
17	275	4	4	1	10
18	280	4	4	1	11
22	308	4	4	1	12

no. lves	ELA	clone	size	block	time
6	32	1	1	1	1
6	24	1	1	1	2
5	31	1	1	1	3
5	31	1	1	1	4
4	26	1	1	1	5
4	24	1	1	1	6
6	21	1	1	1	7
7	24	1	1	1	8
8	41	1	1	1	9
*	*	1	1	1	10
*	*	1	1	1	11
*	*	1	1	1	12
10	37	2	4	1	1
7	28	2	4	1	2
9	42	2	4	1	3
9	51	2	4	1	4
8	45	2	4	1	5
8	53	2	4	1	6
9	50	2	4	1	7
10	87	2	4	1	8
10	101	2	4	1	9
9	101	2	4	1	10
10	83	2	4	1	11
8	52	2	4	1	12
9	46	4	1	1	1
8	30	4	1	1	2
7	49	4	1	1	3
7	58	4	1	1	4
6	66	4	1	1	5
6	65	4	1	1	6
8	36	4	1	1	7
10	51	4	1	1	8
11	64	4	1	1	9
8	55	4	1	1	10
9	57	4	1	1	11
10	50	4	1	1	12
9	30	2	1	1	1
7	22	2	1	1	2
6	31	2	1	1	3
8	32	2	1	1	4
7	35	2	1	1	5
8	39	2	1	1	6
10	34	2	1	1	7
11	52	2	1	1	8
11	101	2	1	1	9
12	76	2	1	1	10
11	70	2	1	1	11
12	84	2	1	1	12
9	42	1	4	1	1
8	42	1	4	1	2
8	45	1	4	1	3
9	54	1	4	1	4
8	48	1	4	1	5
8	53	1	4	1	6
9	38	1	4	1	7
12	53	1	4	1	8
14	59	1	4	1	9
13	57	1	4	1	10
13	47	1	4	1	11
17	61	1	4	1	12

no. lves	ELA	clone	size	block	time
9	29	5	4	1	1
5	27	5	4	1	2
5	43	5	4	1	3
5	36	5	4	1	4
5	34	5	4	1	5
5	36	5	4	1	6
6	26	5	4	1	7
8	36	5	4	1	8
7	42	5	4	1	9
9	43	5	4	1	10
9	49	5	4	1	11
12	65	5	4	1	12
10	26	3	4	1	1
9	32	3	4	1	2
9	32	3	4	1	3
7	43	3	4	1	4
6	38	3	4	1	5
5	39	3	4	1	6
9	44	3	4	1	7
11	58	3	4	1	8
11	65	3	4	1	9
11	73	3	4	1	10
11	61	3	4	1	11
10	56	3	4	1	12
13	35	3	4	1	1
11	34	3	4	1	2
10	55	3	4	1	3
11	57	3	4	1	4
10	49	3	4	1	5
13	68	3	4	1	6
11	54	3	4	1	7
16	71	3	4	1	8
16	99	3	4	1	9
12	104	3	4	1	10
11	68	3	4	1	11
10	80	3	4	1	12
9	23	5	1	1	1
8	22	5	1	1	2
5	26	5	1	1	3
5	26	5	1	1	4
5	34	5	1	1	5
6	36	5	1	1	6
8	33	5	1	1	7
9	34	5	1	1	8
10	43	5	1	1	9
7	35	5	1	1	10
6	31	5	1	1	11
4	21	5	1	1	12
9	28	3	1	1	1
*	*	3	1	1	2
*	*	3	1	1	3
*	*	3	1	1	4
*	*	3	1	1	5
*	*	3	1	1	6
*	*	3	1	1	7
*	*	3	1	1	8
*	*	3	1	1	9
*	*	3	1	1	10
*	*	3	1	1	11
*	*	3	1	1	12

no. lves	ELA	clone	size	block	time
12	24	5	1	3	1
11	40	5	1	3	2
12	60	5	1	3	3
9	83	5	1	3	4
9	80	5	1	3	5
9	88	5	1	3	6
9	87	5	1	3	7
9	94	5	1	3	8
9	99	5	1	3	9
8	79	5	1	3	10
10	57	5	1	3	11
13	47	5	1	3	12
9	21	4	1	3	1
8	24	4	1	3	2
7	31	4	1	3	3
8	33	4	1	3	4
8	37	4	1	3	5
10	44	4	1	3	6
12	37	4	1	3	7
14	43	4	1	3	8
14	45	4	1	3	9
13	43	4	1	3	10
13	37	4	1	3	11
12	33	4	1	3	12
21	34	3	4	3	1
15	34	3	4	3	2
17	35	3	4	3	3
18	47	3	4	3	4
17	40	3	4	3	5
17	50	3	4	3	6
20	46	3	4	3	7
22	52	3	4	3	8
21	53	3	4	3	9
23	58	3	4	3	10
26	64	3	4	3	11
34	62	3	4	3	12
15	33	5	4	3	1
15	26	5	4	3	2
16	41	5	4	3	3
16	36	5	4	3	4
17	42	5	4	3	5
20	52	5	4	3	6
18	53	5	4	3	7
22	85	5	4	3	8
25	150	5	4	3	9
27	171	5	4	3	10
27	239	5	4	3	11
36	233	5	4	3	12
17	42	2	4	3	1
12	45	2	4	3	2
14	53	2	4	3	3
13	52	2	4	3	4
13	53	2	4	3	5
13	54	2	4	3	6
12	61	2	4	3	7
13	56	2	4	3	8
15	63	2	4	3	9
15	54	2	4	3	10
13	55	2	4	3	11
15	52	2	4	3	12

no. lves	ELA	clone	size	block	time
4	10	2	1	3	1
4	13	2	1	3	2
5	17	2	1	3	3
5	15	2	1	3	4
5	14	2	1	3	5
4	15	2	1	3	6
4	12	2	1	3	7
4	12	2	1	3	8
4	15	2	1	3	9
5	17	2	1	3	10
6	17	2	1	3	11
7	18	2	1	3	12
9	38	4	4	3	1
10	62	4	4	3	2
9	42	4	4	3	3
8	57	4	4	3	4
7	47	4	4	3	5
7	61	4	4	3	6
7	28	4	4	3	7
9	42	4	4	3	8
7	54	4	4	3	9
8	35	4	4	3	10
5	21	4	4	3	11
9	30	4	4	3	12
11	18	5	1	3	1
9	24	5	1	3	2
11	24	5	1	3	3
8	20	5	1	3	4
8	22	5	1	3	5
8	30	5	1	3	6
4	12	5	1	3	7
7	24	5	1	3	8
8	27	5	1	3	9
9	28	5	1	3	10
10	27	5	1	3	11
9	23	5	1	3	12
12	37	3	4	3	1
10	29	3	4	3	2
15	44	3	4	3	3
11	51	3	4	3	4
12	49	3	4	3	5
13	52	3	4	3	6
11	54	3	4	3	7
15	57	3	4	3	8
15	68	3	4	3	9
12	62	3	4	3	10
12	48	3	4	3	11
9	35	3	4	3	12
12	26	3	1	3	1
8	32	3	1	3	2
7	33	3	1	3	3
9	37	3	1	3	4
9	35	3	1	3	5
10	51	3	1	3	6
8	29	3	1	3	7
8	39	3	1	3	8
9	34	3	1	3	9
9	32	3	1	3	10
10	33	3	1	3	11
11	35	3	1	3	12

no. lves	ELA	clone	size	block	time
15	27	5	4	3	1
11	27	5	4	3	2
13	40	5	4	3	3
13	40	5	4	3	4
14	38	5	4	3	5
13	40	5	4	3	6
10	33	5	4	3	7
9	33	5	4	3	8
11	39	5	4	3	9
13	38	5	4	3	10
16	39	5	4	3	11
16	33	5	4	3	12
12	26	4	4	3	1
8	30	4	4	3	2
9	48	4	4	3	3
9	48	4	4	3	4
9	51	4	4	3	5
9	51	4	4	3	6
8	52	4	4	3	7
13	60	4	4	3	8
16	70	4	4	3	9
16	66	4	4	3	10
12	72	4	4	3	11
13	64	4	4	3	12
21	47	3	1	3	1
15	43	3	1	3	2
15	57	3	1	3	3
15	64	3	1	3	4
15	77	3	1	3	5
15	91	3	1	3	6
14	82	3	1	3	7
16	64	3	1	3	8
19	110	3	1	3	9
17	94	3	1	3	10
11	64	3	1	3	11
17	93	3	1	3	12
17	52	2	4	3	1
12	49	2	4	3	2
10	65	2	4	3	3
11	73	2	4	3	4
11	74	2	4	3	5
12	88	2	4	3	6
11	67	2	4	3	7
15	89	2	4	3	8
15	87	2	4	3	9
15	88	2	4	3	10
15	57	2	4	3	11
8	26	2	4	3	12
9	26	1	1	3	1
8	25	1	1	3	2
7	39	1	1	3	3
6	44	1	1	3	4
7	46	1	1	3	5
8	52	1	1	3	6
10	65	1	1	3	7
11	72	1	1	3	8
11	71	1	1	3	9
14	77	1	1	3	10
14	74	1	1	3	11
12	63	1	1	3	12

Appendix V e Number of leaves and ELA for subset; year 2.

Clone identification as before. Size as before. Time is assessment number.

no. lves	ELA	clone	class	block	time
7	71	3	1	1	1
9	144	3	1	1	2
7	102	3	1	1	3
6	66	3	1	1	4
5	94	3	1	1	5
4	97	3	1	1	6
4	107	3	1	1	7
3	9	3	1	1	8
4	14	3	1	1	9
5	21	3	1	1	10
18	113	1	4	1	1
15	282	1	4	1	2
16	407	1	4	1	3
16	466	1	4	1	4
17	513	1	4	1	5
19	658	1	4	1	6
20	705	1	4	1	7
28	561	1	4	1	8
26	389	1	4	1	9
28	280	1	4	1	10
8	41	1	1	1	1
9	17	1	1	1	2
5	43	1	1	1	3
10	42	1	1	1	4
11	96	1	1	1	5
11	149	1	1	1	6
14	186	1	1	1	7
23	119	1	1	1	8
14	92	1	1	1	9
3	18	1	1	1	10
*	*	4	4	1	1
*	*	4	4	1	2
*	*	4	4	1	3
1	2	4	4	1	4
*	*	4	4	1	5
1	2	4	4	1	6
2	4	4	4	1	7
3	5	4	4	1	8
2	4	4	4	1	9
3	4	4	4	1	10
12	145	4	1	1	1
9	426	4	1	1	2
9	202	4	1	1	3
9	407	4	1	1	4
3	321	4	1	1	5
2	204	4	1	1	6
2	147	4	1	1	7
5	27	4	1	1	8
*	*	4	1	1	9
*	*	4	1	1	10
15	116	5	1	1	1
7	159	5	1	1	2
6	121	5	1	1	3
*	*	5	1	1	4
5	192	5	1	1	5
5	247	5	1	1	6
4	235	5	1	1	7
6	79	5	1	1	8
8	22	5	1	1	9
7	52	5	1	1	10

no. lves	ELA	clone	class	block	time
20	224	4	4	1	1
13	359	4	4	1	2
14	281	4	4	1	3
13	403	4	4	1	4
13	287	4	4	1	5
14	292	4	4	1	6
20	480	4	4	1	7
31	202	4	4	1	8
28	188	4	4	1	9
28	248	4	4	1	10
6	21	2	4	1	1
4	21	2	4	1	2
5	27	2	4	1	3
4	16	2	4	1	4
3	12	2	4	1	5
4	21	2	4	1	6
3	20	2	4	1	7
5	29	2	4	1	8
5	25	2	4	1	9
7	41	2	4	1	10
7	72	1	4	1	1
8	251	1	4	1	2
8	123	1	4	1	3
8	139	1	4	1	4
3	78	1	4	1	5
3	103	1	4	1	6
3	76	1	4	1	7
10	22	1	4	1	8
8	25	1	4	1	9
7	18	1	4	1	10
9	78	5	4	1	1
9	189	5	4	1	2
8	100	5	4	1	3
8	121	5	4	1	4
7	149	5	4	1	5
6	124	5	4	1	6
7	135	5	4	1	7
9	148	5	4	1	8
8	68	5	4	1	9
11	82	5	4	1	10
1	3	3	4	1	1
*	*	3	4	1	2
*	*	3	4	1	3
3	3	3	4	1	4
3	3	3	4	1	5
3	3	3	4	1	6
2	2	3	4	1	7
5	6	3	4	1	8
6	7	3	4	1	9
5	6	3	4	1	10
*	*	3	4	1	1
*	*	3	4	1	2
*	*	3	4	1	3
*	*	3	4	1	4
4	3	3	4	1	5
2	3	3	4	1	6
1	1	3	4	1	7
4	8	3	4	1	8
4	12	3	4	1	9
*	*	3	4	1	10

no. lves	ELA	clone	class	block	time
6	52	1	1	3	1
6	206	1	1	3	2
3	10	1	1	3	3
3	32	1	1	3	4
6	39	1	1	3	5
6	59	1	1	3	6
9	52	1	1	3	7
14	58	1	1	3	8
15	55	1	1	3	9
16	63	1	1	3	10
24	245	1	4	3	1
19	334	1	4	3	2
19	223	1	4	3	3
4	74	1	4	3	4
6	54	1	4	3	5
7	26	1	4	3	6
11	39	1	4	3	7
18	118	1	4	3	8
21	75	1	4	3	9
12	45	1	4	3	10
7	35	2	1	3	1
9	36	2	1	3	2
10	49	2	1	3	3
13	42	2	1	3	4
7	24	2	1	3	5
4	6	2	1	3	6
8	8	2	1	3	7
11	10	2	1	3	8
6	15	2	1	3	9
*	*	2	1	3	10
24	302	4	1	3	1
24	320	4	1	3	2
21	353	4	1	3	3
14	260	4	1	3	4
7	174	4	1	3	5
13	282	4	1	3	6
16	193	4	1	3	7
22	86	4	1	3	8
33	77	4	1	3	9
30	100	4	1	3	10
8	26	5	1	3	1
8	26	5	1	3	2
5	19	5	1	3	3
*	*	5	1	3	4
6	19	5	1	3	5
6	24	5	1	3	6
5	27	5	1	3	7
4	15	5	1	3	8
2	5	5	1	3	9
*	*	5	1	3	10
4	11	4	1	3	1
5	11	4	1	3	2
4	8	4	1	3	3
*	*	4	1	3	4
5	9	4	1	3	5
6	9	4	1	3	6
4	8	4	1	3	7
5	11	4	1	3	8
3	12	4	1	3	9
*	*	4	1	3	10

no. lves	ELA	clone	class	block	time
12	156	3	4	3	1
19	235	3	4	3	2
16	342	3	4	3	3
*	*	3	4	3	4
15	141	3	4	3	5
15	221	3	4	3	6
18	225	3	4	3	7
21	196	3	4	3	8
21	56	3	4	3	9
17	55	3	4	3	10
32	287	5	4	3	1
36	225	5	4	3	2
27	427	5	4	3	3
*	*	5	4	3	4
25	359	5	4	3	5
31	752	5	4	3	6
21	306	5	4	3	7
33	415	5	4	3	8
27	188	5	4	3	9
34	99	5	4	3	10
11	48	2	4	3	1
15	112	2	4	3	2
13	99	2	4	3	3
4	32	2	4	3	4
3	30	2	4	3	5
6	30	2	4	3	6
6	36	2	4	3	7
14	44	2	4	3	8
12	79	2	4	3	9
10	45	2	4	3	10
3	28	2	1	3	1
3	34	2	1	3	2
4	52	2	1	3	3
2	16	2	1	3	4
2	14	2	1	3	5
2	13	2	1	3	6
3	15	2	1	3	7
5	37	2	1	3	8
2	3	2	1	3	9
*	*	2	1	3	10
7	40	4	4	3	1
6	55	4	4	3	2
3	25	4	4	3	3
*	*	4	4	3	4
*	*	4	4	3	5
*	*	4	4	3	6
1	1	4	4	3	7
1	1	4	4	3	8
2	3	4	4	3	9
2	3	4	4	3	10
*	*	5	1	3	1
*	*	5	1	3	2
*	*	5	1	3	3
1	2	5	1	3	4
3	3	5	1	3	5
5	13	5	1	3	6
3	18	5	1	3	7
*	*	5	1	3	8
*	*	5	1	3	9
*	*	5	1	3	10

no. lves	ELA	clone	class	block	time
10	25	3	4	3	1
8	39	3	4	3	2
9	45	3	4	3	3
10	33	3	4	3	4
7	44	3	4	3	5
8	33	3	4	3	6
8	38	3	4	3	7
7	39	3	4	3	8
11	95	3	4	3	9
10	36	3	4	3	10
6	35	3	1	3	1
6	46	3	1	3	2
6	62	3	1	3	3
*	*	3	1	3	4
*	*	3	1	3	5
*	*	3	1	3	6
1	1	3	1	3	7
4	15	3	1	3	8
5	61	3	1	3	9
8	45	3	1	3	10
12	77	5	4	3	1
12	131	5	4	3	2
8	79	5	4	3	3
10	224	5	4	3	4
10	147	5	4	3	5
10	123	5	4	3	6
10	170	5	4	3	7
11	110	5	4	3	8
11	76	5	4	3	9
11	50	5	4	3	10
10	24	4	4	3	1
10	30	4	4	3	2
9	23	4	4	3	3
9	19	4	4	3	4
9	26	4	4	3	5
9	27	4	4	3	6
10	37	4	4	3	7
13	40	4	4	3	8
12	32	4	4	3	9
14	40	4	4	3	10
*	*	3	1	3	1
2	11	3	1	3	2
2	17	3	1	3	3
3	20	3	1	3	4
*	*	3	1	3	5
3	10	3	1	3	6
*	*	3	1	3	7
4	12	3	1	3	8
*	*	3	1	3	9
*	*	3	1	3	10
14	41	1	1	3	1
10	26	1	1	3	2
10	32	1	1	3	3
15	31	1	1	3	4
10	49	1	1	3	5
3	31	1	1	3	6
11	49	1	1	3	7
22	58	1	1	3	8
9	45	1	1	3	9
9	25	1	1	3	10

Appendix V f Flowering of field grown plants over 2 seasons.

Cap1= capitula produced in season 1. Cap2= capitula produced in season 2.

Viy1= number viable year 1. Viy2= number viable year 2.

Wty1= total weight of achenes year 1. Wty2=total weight of achenes year 2.

w1cap1	w1cap2	w3cap1	w3cap2	w5cap1	w5cap2
1	1	1	0	0	1
0	1	1	0	1	0
3	11	1	0	1	0
1	0	1	0	1	0
1	2	1	3	1	0
2	14			2	1
1	0				

m1cap1	m1cap2	m2cap1	m2cap2	w1viy1	w1viy2
0	1	1	2	200	200
1	0	1	0	0	132
0	5	1	1	460	1513
1	0	0	19	182	0
1	1			215	320
2	0			394	1963
				209	0

w1s1vi	w1s2vi	w1s1wt	w1s2wt	w3s1vi	w3s2vi
2341	454	1.9879	0.2801	1823	167
1903	319	1.2086	0.1344	1996	455
2817	328	1.8642	0.1574	2129	0
1991	347	1.2829	0.2203	2698	141
1339	1630	0.6517	0.8440	2303	210
2658	311	1.5548	0.2118	1948	0
2347	564	1.3673	0.2412	2287	0
1840	714	1.0228	0.3526	1698	0
3475	106	1.9957	0.0297	1855	629
1817	190	1.1220	0.0773		

m2s1vi	m2s2vi	m2s1wt	m2s2wt
2712	102	1.3791	0.0417
2835	353	1.4880	0.1710
2257	274	1.1241	0.1135
2914	221	1.4761	0.1908
2677	167	1.4028	0.0680
2990	238	1.5909	0.0593
956	0	0.3942	0.0000
2282	0	1.0855	0.0000
3437	98	1.7920	0.0391
2822	0	1.3742	0.0000

w3s1wt	w3s2wt	w5s1vi	w5s2vi	w5s1wt	w5s2wt
0.9144	0.0607	2728	0	1.2663	0.0000
0.8237	0.1873	2362	308	1.2052	0.1335
1.0592	0.0000	2596	0	1.2014	0.0000
1.6371	0.0459	1547	132	0.7486	0.0526
1.1223	0.0745				
0.9312	0.0000				
1.0260	0.0000				
0.8390	0.0000				
0.6897	0.2592				

w1wty1	w1wty2	w3viy1	w3viy2	w3wty1	w3wty2
0.0890	0.0928	123	0	0.0479	0.0000
0.0000	0.1045	170	0	0.0706	0.0000
0.2980	0.8242	108	0	0.0559	0.0000
0.0605	0.0000	169	0	0.0706	0.0000
0.0890	0.1061	72	298	0.0297	0.1841
0.2302	1.2696				
0.0800	0.0000				

w5viy1	w5viy2	w5wty1	w5wty2	m1viy1	m1viy2
0	136	0.0000	0.0917	0	204
158	0	0.0517	0.0000	137	0
155	0	0.0667	0.0000	0	879
0	204	0.0000	0.1725	83	0
166	0	0.0764	0.0000	121	58
173	0	0.0846	0.0000	303	1
254	138	0.0729	0.0721		

m1wty1	m1wty2	m2viy1	m2viy2	m2wty1	m2wty2
0.0000	0.1725	141	111	0.0703	0.0586
0.0723	0.0000	0	2182	0.0000	1.3761
0.0000	0.8155	129	146	0.0459	0.0939
0.0542	0.0000	165	0	0.0415	0.0000
0.0675	0.0472				
0.0796	0.0683				

Appendix V g

Environmental sensitivity: root crown diameter and dry weight.

environ	RCD	Dwt	W1RCD	W1Dwt	W3RCD	W3Dwt	W5RCD
pot 1	20.68	2.74	16.10	2.80	21.70	2.75	20.85
soil 1	32.06	13.30	30.34	14.59	36.81	16.21	34.46
grass 1	14.52	2.33	12.98	1.84	14.41	2.34	14.00
pot 2	17.61	2.54	16.24	1.73	18.58	3.19	18.33
soil 2	14.63	5.06	16.23	4.47	16.18	4.59	16.76
grass 2	11.27	1.15	10.95	0.75	11.26	1.19	11.41
>0.7mg	18.95	4.00	17.55	3.01	18.65	2.86	20.47
grnhouse	25.18	20.06	22.60	23.38	25.50	19.58	25.50
NFT	24.72	38.45	25.00	46.64	23.30	32.49	21.30

environ	RCD	Dwt	W1RCD	W1Dwt	W3RCD	W3Dwt	W5RCD
pot 1	20.68	2.74	16.10	2.80	21.70	2.75	20.85
soil 1	32.06	13.30	30.34	14.59	36.81	16.21	34.46
grass 1	14.52	2.33	12.98	1.84	14.41	2.34	14.00
pot 2	17.61	2.54	16.24	1.73	18.58	3.19	18.33
soil 2	14.63	5.06	16.23	4.47	16.18	4.59	16.76
grass 2	11.27	1.15	10.95	0.75	11.26	1.19	11.41
>0.7mg	18.95	4.00	17.55	3.01	18.65	2.86	20.47
grnhouse	25.18	20.06	22.60	23.38	25.50	19.58	25.50
NFT	24.72	38.45	25.00	46.64	23.30	32.49	21.30

W5Dwt	M1RCD	M1Dwt	M2RCD	M2Dwt
2.94	21.45	3.07	23.04	2.16
12.31	29.99	12.76	29.21	10.64
2.11	15.87	3.11	15.34	2.24
2.22	17.46	2.51	17.43	3.05
4.39	18.13	6.98	15.87	4.87
1.10	12.20	1.76	10.54	0.93
5.13	19.76	5.79	18.31	3.23
18.56	28.60	19.96	23.57	18.81
28.46	32.90	57.96	21.10	26.69